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Inorganic Arsenic Emissions from
Low-Arsenic Primary Copper Smelters
Background Information for Proposed Standards

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

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Low-Arsenic Primary Copper Smelters -
Background Information
for Proposed Standards**

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

April 1983

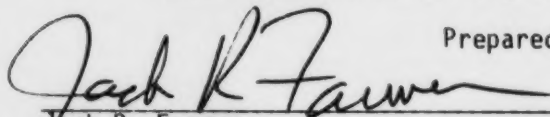
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ENVIRONMENTAL PROTECTION AGENCY

Background Information and Draft
Environmental Impact Statement
for Primary Copper Smelters Processing
Feed Materials Containing Less Than 0.7 Percent Arsenic

Prepared by:



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Research Triangle Park, NC 27711

6/23/83
(Date)

1. The proposed standards of performance would limit emissions of inorganic arsenic from existing and new primary copper smelters processing feed materials containing less than 0.7 percent arsenic. The proposed standards implement Section 112 of the Clean Air Act and are based on the Administrator's determination of June 5, 1980 (45 FR 37886), that inorganic arsenic presents a significant risk to human health as a result of air emissions from one or more stationary source categories, and is therefore a hazardous air pollutant. Of the 14 primary copper smelters which would be affected, seven are located in Arizona, two in New Mexico, and one each in Nevada, Texas, Utah, Tennessee, and Michigan.
2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.
3. The comment period for review of this document is 60 days. Mr. Gene W. Smith may be contacted regarding the date of the comment period.
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1.0 SUMMARY

1.1 STATUTORY AUTHORITY

National emission standards for hazardous air pollutants are established in accordance with Section 112(b)(1)(B) of the Clean Air Act (U.S.C. 7412), as amended. Emission standards under Section 112 apply to new and existing sources of a substance that has been listed as a hazardous pollutant. This study examines inorganic arsenic emissions from primary copper smelters which process feed material with an annual average inorganic arsenic content of less than 0.7 percent by weight. This category of primary copper smelters is defined as "low-arsenic throughput smelters." There are currently 14 primary copper smelters in this category, and none of them is expected to increase the annual average inorganic arsenic content of its feed materials to or above 0.7 percent. The single existing high-arsenic throughput smelter, owned and operated by ASARCO, Incorporated, and located in Tacoma, Washington, is not expected to decrease the annual average inorganic arsenic content of its feed materials to below 0.7 percent and no new smelters are projected to be built during the next 5 years. For this reason, only the 14 existing low-arsenic throughput primary copper smelters are analyzed in this document with respect to the environmental, energy, and economic impacts of regulating the low-arsenic throughput smelter category. The existing high-arsenic throughput copper smelter is analyzed in the document, "Inorganic Arsenic Emissions from High-Arsenic Primary Copper Smelters - Background Information for Proposed Standards" (EPA-450/3-83-009a).

1.2 REGULATORY ALTERNATIVES

Review of the technical support data led to the development of five regulatory alternatives. Alternative I would require no additional regulatory action. This alternative would rely on existing regulations and existing controls to limit emissions of inorganic arsenic.

Alternative II would require the control of process arsenic emissions. This alternative is based on the use of flue gas cooling followed by a particulate control device to collect process arsenic emissions.

Sources of process arsenic emissions include the roasters, smelting furnaces, and copper converters.

Alternative III would require the capture of fugitive arsenic emissions from converter operations and the collection of these fugitive emissions in a particulate control device. Fugitive emissions are those that escape capture and control through the primary control equipment. This alternative is based on the use of an air curtain secondary hood consisting of a fixed enclosure and an air curtain system followed by a particulate control device (baghouse or equivalent technology).

Alternative IV would require the capture of fugitive emissions from furnace slag tapping operations and the collection of inorganic arsenic emissions from furnace slag tapping and matte tapping operations. This alternative is based on the use of localized hoods to capture the slag tapping fugitive emissions and a particulate control device (baghouse or equivalent technology) to collect the inorganic arsenic emissions from both furnace slag tapping and matte tapping.

Alternative V would require the elimination of all arsenic emissions at copper smelters. To accomplish this alternative the smelters would be forced to process ores which were virtually free of arsenic content.

1.3 ENVIRONMENTAL IMPACTS

Under Alternative I there would be no additional inorganic arsenic reduction from the baseline because there is no additional regulatory action associated with Alternative I. Under Alternative II, inorganic arsenic emissions from process sources would be reduced by 163 megagrams per year (Mg/yr). This represents a 30 percent reduction in process inorganic arsenic emissions and a 22 percent reduction in overall inorganic arsenic emissions from the low-arsenic copper smelter category. Energy requirements at the one smelter affected by Alternative II would increase by 4.9×10^8 kWh. This represents a 33 percent increase in the energy requirements at the one affected smelter. Solid waste increases at the affected smelter would amount to 16,300 Mg/yr. This represents a 0.5 percent increase in solid waste which must be handled by the smelter.

Under Alternative III, fugitive arsenic emissions from converter operations would be reduced by 118 Mg/yr. This represents a reduction of 60 percent in fugitive inorganic arsenic emissions and a reduction

of 16 percent in overall inorganic arsenic from the source category. Energy requirements for this alternative would increase by 1.8×10^8 kWh. This represents a 0.35 percent increase in energy requirements for the source category. Solid wastes generated would increase by 11,800 Mg/yr, which represents a 0.4 percent increase for the source category.

Under Alternative IV, fugitive inorganic arsenic emissions from matte and slag tapping operations would be reduced by 11 Mg/yr. This represents a reduction of 5 percent in fugitive arsenic emissions and a reduction of 1.5 percent in overall inorganic arsenic emissions from the source category. Energy requirements for the source category would increase by 9×10^6 kWh, which represents a 0.02 percent increase in energy requirements. Increases in solid wastes generated would amount to 1,100 Mg/yr, or an increase of 0.03 percent for the source category.

The air quality, energy, and solid waste impacts, as well as all environmental and economic impacts, are summarized in Table 1-1.

The control systems for the regulatory alternatives are dry systems; consequently, no incremental increase in water discharges is anticipated. If scrubbers are used, increases in wastewater discharges would result and the scrubber discharge would be treated within existing water pollution control systems. Therefore, even if scrubbers are used, no adverse water pollution impact is anticipated.

The regulatory alternatives would result in negligible impacts on noise, space, and availability of resources.

1.4 ECONOMIC IMPACTS

The total capital cost for the process controls specified under Alternative II is \$9.8 million. The annualized cost for the controls at the Kennecott-McGill smelter would be \$4.1 million. The total annualized cost for this alternative, coupled with the annual emission reduction expected under Alternative II, would yield an annualized cost-effectiveness of \$25,200/Mg of inorganic arsenic reduced. The total capital cost for the fugitive emission controls for the converter operations specified under Alternative III is \$109.9 million. The annualized cost of these converter controls would be \$29.2 million. The total annualized costs associated with the converter controls,

Table 1-1. ASSESSMENT OF ENVIRONMENTAL AND ECONOMIC IMPACTS FOR EACH REGULATORY ALTERNATIVE CONSIDERED

Regulatory Alternative	Air Impact	Water Impact	Solid Waste Impact	Energy Impact	Noise Impact	Economic Impact
I	0	0		0	0	0
II	+2**	-1*	-1*	-1**	-1*	-4**
III	+2**	-1*	-1*	-1**	-1*	-3**
IV	+2**	-1*	-1*	-1**	-1*	-3**
V	+4**	+4**	-3**	+4**	+1**	-4**

Key: + Beneficial Impact

- Adverse Impact

0 No impact

1 Negligible Impact

2 Small Impact

3 Moderate Impact

4 Large Impact

* Short-Term Impact

** Long-Term Impact

*** Irreversible Impact

coupled with the emission reduction expected under Alternative III, would yield an annualized cost-effectiveness of \$247,000/Mg of inorganic arsenic reduced.

The total capital cost for the fugitive emission controls for the matte and slag tapping operations specified under Alternative IV is \$14.8 million. The annualized cost associated with these fugitive emission controls would be \$4.3 million. The total annualized cost of these matte and slag tapping fugitive emission controls, coupled with the emission reduction expected under Alternative IV, would yield an annualized cost-effectiveness of \$389,000/Mg of inorganic arsenic reduced.

In 1982, copper producers experienced one of the worst years in recent history. Such a situation cannot be used as the foundation to examine the long-term economic impact of the potential arsenic NESHAP. Therefore, the economic analysis is based on a more normal condition for the industry. The principal economic impacts analyzed are: the ability of the smelters to increase copper prices in response to an increase in costs due to the arsenic standard; and, the impact on profits if part or all of the costs cannot be passed on in the form of price increases.

If each smelter attempts to maintain its normal profit margin and pass control costs forward in the form of a price increase, the price increases would range from 0.1 percent to 15.2 percent. However, competition will prevent the existence of such a broad variation. If control costs are absorbed and profit margins reduced, again a broad range exists. The profit reductions would range from 0.4 percent to 151.9 percent. At a 100 percent capacity utilization rate and a price of 187¢/kg, two smelters would experience a serious profit reduction of more than 40 percent.

Although the capital costs of the control equipment are not minor amounts, for most of the producers the capital cost does not present a major obstacle. For two of the producers the capital costs may present some difficulty.

Alternative V, which would eliminate arsenic emissions from the low-arsenic throughput smelter category would result in closing of all the smelters in the source category. Although this results in the greatest emission reduction, the economic impacts and hardships associated with this alternative are severe.

Alternative V, which would eliminate arsenic emissions from the low-arsenic throughput smelter category would result in closing of all the smelters in the source category. Although this results in the greatest emission reduction, the economic impacts and hardships associated with this alternative are severe.

2.0 THE PRIMARY COPPER INDUSTRY

2.1 GENERAL

Currently, there are 15 primary copper smelters operating or temporarily closed in the United States. Of these, seven are located in Arizona, two in New Mexico, and one each in Nevada, Texas, Utah, Tennessee, Michigan, and Washington. The concentration of copper smelters in the Southwest is due mainly to the local availability of copper-bearing ores. For the 15 copper smelters, smelting capacity totals approximately 1.72 million Mg (1.9 million tons) of smelter product (99 percent "blister" copper) per year.¹ Table 2-1 lists these 15 smelters, their locations, and estimated capacities.

Primary copper production in 1982 was 975,437 Mg (1,075,400 tons).² This represented approximately a 60 percent utilization of domestic primary copper smelting capacity. Smelter capacity in the United States appears to be relatively steady, with minimal prospects for substantial additions before 1985. The Bureau of Mines forecasts the total demand for copper in the year 2000 to be between 3.5 and 6.0 teragrams (Tg) (3.9×10^6 and 6.6×10^6 tons). This forecast represents an annual growth of 3.6 percent. However, recycling of scrap and the expansion of hydrometallurgical facilities are expected to accommodate a substantial portion of this increased demand.³

2.1.1 Raw Materials

Copper ores are generally classified as sulfide, oxide, or native depending on the predominant copper-bearing minerals they contain. Although copper occurs in at least 160 minerals, only a few of these have any commercial importance. Table 2-2 lists the composition of the more important sulfide and oxide minerals from which copper is extracted. Of the primary sulfide minerals, chalcopyrite is the most abundant, followed by bornite and chalcocite. Oxide minerals are produced by the oxidation of primary sulfide minerals under certain

Table 2-1. DOMESTIC PRIMARY COPPER SMELTERS

Company	Location	Annual capacity ^a	
		Megagrams	(Tons)
ASARCO, Incorporated	El Paso, Texas	91,000	(100,000)
	Hayden, Arizona	182,000	(200,000)
	Tacona, Washington	91,000	(100,000)
Tennessee Chemical Company	Copperhill, Tennessee	13,600	(15,000)
Inspiration Consolidated Copper Company	Miami, Arizona	136,000	(150,000)
Kennecott Copper Corporation	Garfield, Utah	254,000	(280,000)
	Hayden, Arizona	71,000	(78,000)
	Hurley, New Mexico	73,000	(80,000)
	McGill, Nevada	45,000	(50,000)
Magma Copper Company	San Manuel, Arizona	181,000	(200,000)
Phelps Dodge Corporation	Ajo, Arizona	64,000	(70,000)
	Douglas, Arizona	115,000	(127,000)
	Hidalgo, New Mexico	163,000	(179,000)
	Morenci, Arizona	191,000	(210,000)
Copper Range Company	White Pine, Michigan	52,000	(57,000)
TOTAL		1,722,600	(1,896,000)

^aProduction of "blister" copper (99 percent Cu)

Table 2-2. MAJOR COPPER-BEARING MINERALS

Type	Mineral	Formula
Sulfide	Chalcopyrite	CuFeS_2
	Bornite	Cu_3FeS_3
	Chalcocite	Cu_2S
	Covellite	CuS
Oxide	Malachite	$\text{CuCO}_3 \cdot \text{Cu(OH)}_2$
	Azurite	$2\text{CuCO}_3 \cdot \text{Cu(OH)}_2$
	Chrysocolla	$\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$
	Cuprite	Cu_2O

climatic conditions. When present, these are usually found in the upper portions of copper ore deposits. Native copper consists of almost pure metallic copper. Although found in small amounts in many copper ore deposits, it is essentially unique to the upper peninsula of Michigan.

Copper ores consist of one or more of these copper-bearing minerals disseminated within relatively large quantities of siliceous and other earthy matter. In addition, they also contain varying amounts of other metals including sulfides and oxides of iron, arsenic, antimony, lead, zinc, etc. In the United States, low grade sulfide ores account for 85 to 95 percent of the total primary production.⁴ The average tenor of these ores (copper content) is less than 1 percent.⁵ Virtually all copper ores processed are beneficiated at the mine. Sulfide ores are crushed, finely ground, and concentrated by froth flotation. Oxide ores are leached with acid, and the dissolved copper is recovered by chemical precipitation on scrap iron. Typically, copper ore concentrates contain about 15 to 30 percent copper.

In addition to copper, metals such as arsenic are also concentrated in the concentration process. The arsenic content of copper concentrates processed at U.S. copper smelters is highly variable, ranging from a few parts per million to several percent. The impurities, mainly arsenic and others such as antimony, bismuth, lead, and zinc exert a strong influence on the selection of smelting technology. Table 2-3

Table 2-3. ARSENIC INPUT IN THE FEED TO
DOMESTIC COPPER SMELTERS

Plant	Arsenic content of feed ^{a,b}		
	Percent	kg/hr	(lb/hr)
ASARCO-Tacoma	4.0	991	(2,185)
ASARCO-Hayden	0.6	170	(375)
ASARCO-El Paso	0.5	142 ^d	(314)
Kennecott-Garfield	0.14	118 ^e	(261)
Kennecott-McGill	0.4	81 ^f	(179.3)
Phelps Dodge-Ajo	0.3	47	(103)
Inspiration-Miami	0.033	18 ^g	(41.1)
Phelps Dodge-Hidalgo	0.018	14	(30.6)
Phelps Dodge-Douglas	0.03	11	(24)
Kennecott-Hayden	0.015	8.0	(17.7)
Phelps Dodge-Morenci	0.006	4.5 ^h	(9.99)
Magma-San Manuel	0.006	2.0	(4.39)
Tennessee Chemical Company - Copperhill	0.0004	1.3	(2.9)
Kennecott-Hurley	0.0005	1.0	(2.14)
Copper Range - White Pine	0.008	0.7 ⁱ	(1.53)

^aThe feed is a mixture of concentrates, precipitates, lead smelter by-products, and smelter reverts.

^bDoes not include recycled flue dusts and other intermediates.

^c50 kg/hr (111 lb/hr) of this amount is fed directly to the arsenic plant.

^d51 kg/hr (112 lb/hr) of this amount is fed directly to the converters.

^e3.5 kg/hr (7.8 lb/hr) of this amount is fed directly to the converters.

^f6.5 kg/hr (14.2 lb/hr) of this amount is fed directly to the converters.

^g0.3 kg/hr (0.6 lb/hr) of this amount is fed directly to the converters.

^h0.2 kg/hr (0.35 lb/hr) of this amount is fed directly to the converters.

ⁱ0.1 kg/hr (0.22 lb/hr) of this amount is fed directly to the converters.

presents the amount of arsenic input to the domestic primary copper smelters based on information received from the smelters in early 1983.^{6,7,8,9,10,11,12} The ASARCO-Tacoma smelter, which introduces more arsenic in the feed material to the smelter than the combined total from all of the low-arsenic throughput copper smelters, is analyzed in a separate background information document (EPA-450/3-83-009a).

2.1.2 Process Description¹³

The pyrometallurgical process used for the extraction of copper from sulfide ore concentrates is based on iron's strong affinity for oxygen as compared to copper's weak affinity for oxygen. The purpose of smelting is to separate the copper from the iron, sulfur, and gangue materials. Conventional practice includes three operations:

1. Roasting (optional) to remove a portion of the concentrate sulfur content.
2. Smelting of roasted calcines or unroasted ore concentrates and fluxes in a furnace to form slag and copper-bearing matte.
3. Converting (oxidizing) of the matte in a converter to form blister copper (about 99 percent pure copper).

Figure 2-1 presents a pictorial representation of the copper smelting process. Figure 2-2 illustrates the three basic operations employed as well as materials entering or leaving each operation. Briefly, the smelting of copper concentrates and precipitates is accomplished by melting the charge and suitable fluxes in a smelting furnace. Part or all of the concentrates may receive a partial roast to eliminate some of the sulfur and impurities such as arsenic. In the smelting furnace, the lighter impurities combine and float to the top as slag to be skimmed off and discarded, while the copper, iron, most of the sulfur, and any contained precious metals form a product known as matte which collects in and is drawn off from the lower part of the furnace. The molten matte is transferred to a converter where air blown through the matte burns off the sulfur, oxidizes the iron for removal in a slag, and yields a 99 percent blister copper product. Typically, the blister copper is further refined in an anode furnace prior to the casting of copper anodes for electrolytic refining. A more detailed discussion of roasting, smelting, and converting operations is presented in succeeding paragraphs.

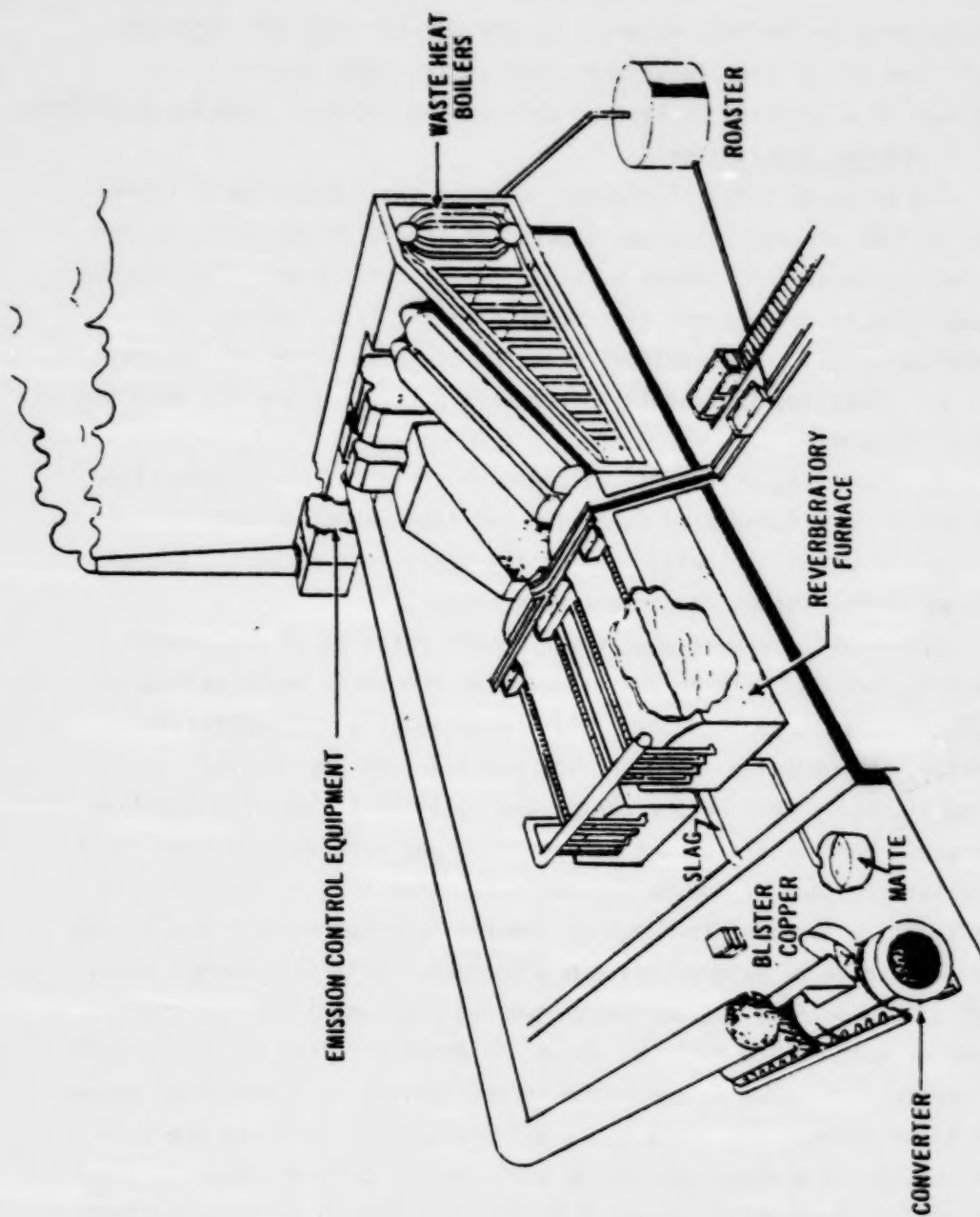


Figure 2-1. Primary Copper Smelter

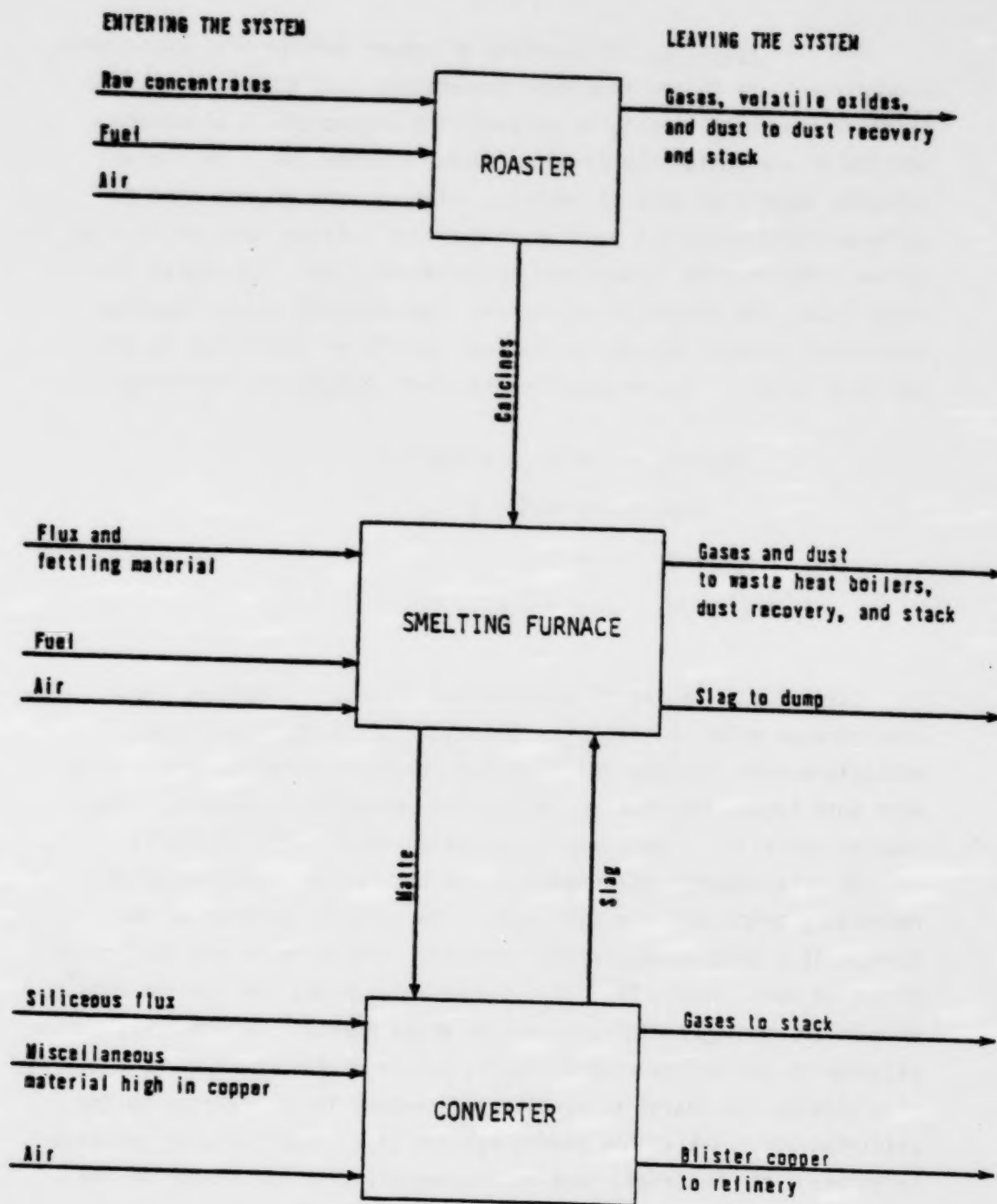


Figure 2-2. Primary Copper Smelting Process

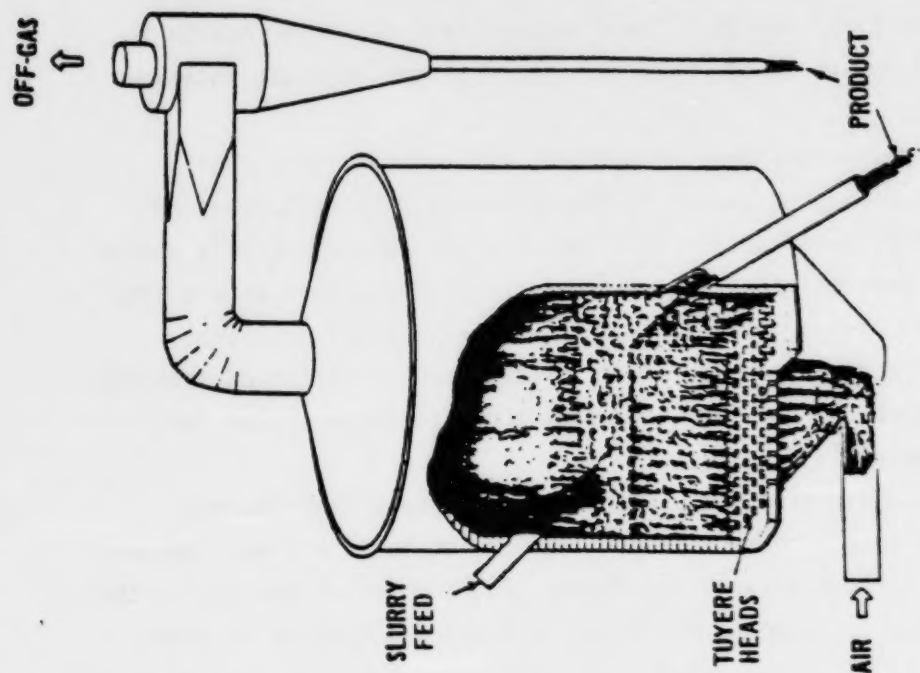
2.1.2.1 Roasting. In roasting of copper sulfide ore concentrates, concentrates are heated to a high temperature (but below the melting point of the constituents) in an oxidizing atmosphere to eliminate a portion of the sulfur contained as sulfur dioxide (SO_2); to remove volatile impurities such as arsenic, antimony, and bismuth; and to preferentially convert a portion of the iron sulfides present to iron oxides. The roasted concentrate is called calcine. The degree of roast (i.e., the amount of sulfur and iron oxidized in the roasting operation) is dependent on the desired quality of the charge to the smelting furnace. Representative reactions include the following:



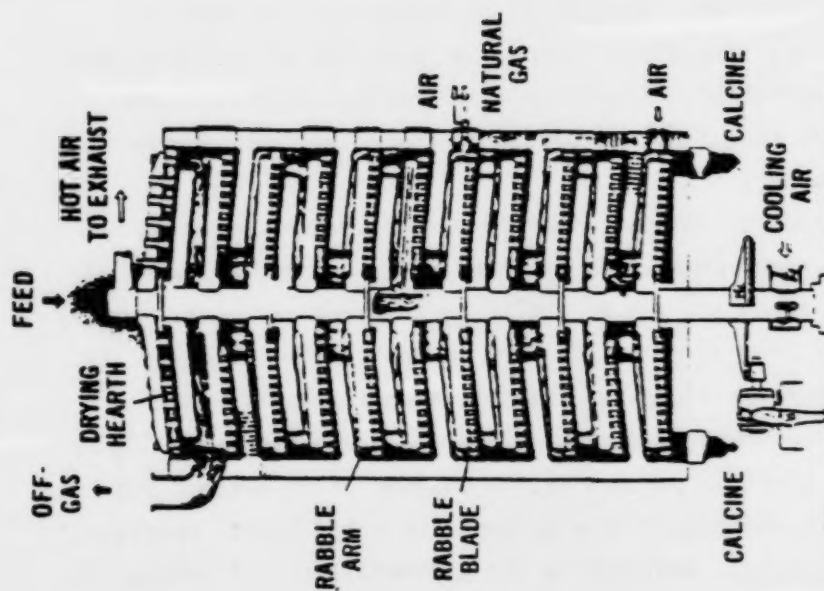
Currently, 7 of the 15 existing primary copper smelters roast concentrates prior to smelting. Two types of roasters are used: multiple-hearth roasters and fluid-bed roasters (refer to Figure 2-3). With both types, the roasting process is generally autogenous. The roaster operating temperature is typically about 650°C ($1,200^\circ\text{F}$).

In multi-hearth type roasters, the hearths are constructed of refractory brick with a slight arch. The external portion of the furnace is a brick-lined, steel shell with hinged doors and inspection plates at each level. The moist concentrate enters the roaster through an annular opening to the top-most or dryer hearth. Rabble arms, attached to the hollow central shaft, rotate as the shaft turns and plow through the charge to continuously expose fresh surfaces to the oxidizing air. The rabble blades are set at an angle and, in addition to stirring the material, move it alternately from the center of the hearth to the periphery where it falls to the next lower hearth. Finished calcine is discharged through holes on the circumference of the bottom hearth.

The air required for roasting is admitted through the central shaft and, by means of valves, the air supply to each hearth may be



FLUID-BED ROASTER



MULTI-HEARTH ROASTER

Figure 2-3. Calcine Roaster

regulated. Roaster gases are drawn off through gas outlets located just below the dryer hearth. The discharge from the dryer hearth to the top roasting hearth prevents the escape of gas from the interior of the roaster.

Fluid-bed roasters are cylindrical, refractory-lined vessels equipped with diffusion plates in the bottom containing tuyeres or bubble caps through which air is blown from the bottom. Finely ground material (60 percent minus 200 mesh) is introduced either as a slurry through a feed pipe or relatively dry (6 to 12 percent moisture) through a screw conveyor. The feed is continuously delivered into the combustion chamber. Roasting occurs as the sulfide particles fall through the oxidizing air.

Combustion air from the windbox passes through distribution plates at the bottom of the chamber into the combustion zone. Because of the large surface area of the finely ground material exposed to the air stream, the residence time in the oxidizing atmosphere is short. The reaction is self-sustaining. Oil, gas, or pulverized coal burners are required only to preheat the roaster to combustion temperature.

Roaster gases are drawn off through flues at the top of the chamber and immediately pass to cyclone collectors, followed by cooling and final dust collection. As much as 85 percent of the feed is carried with the gas stream and, hence, cyclones are an integral part of the roasting operation. Screw conveyors collect this finished calcine as well as that from the bottom of the combustion chamber for discharge into hoppers.

For either type of roaster, there are three major operating variables: feed rate, combustion air flow rate, and temperature. A key difference between the two is the SO_2 concentration in the roaster offgases. Sulfur dioxide concentrations in the roaster offgases are considerably higher for fluid-bed roasters than for multi-hearth roasters due to the lower total air volume. Average stack gas SO_2 concentration is about 12 percent with a maximum of 18 percent for fluid-bed roasters and only 3 to 6 percent for multi-hearth roasters.¹⁴

2.1.2.2 Smelting. Smelting is the pyrometallurgical process in which solid material is melted and subjected to certain chemical

changes. During copper smelting, hot calcines from the roaster or raw, unroasted concentrates are melted in a smelting furnace with siliceous or limestone flux. Converter slag, collected dust, oxide ores, and any other material rich in copper may be added to the furnace charge. Copper and iron which are present in the charge combine with sulfur to form a stable cuprous sulfide. Excess sulfur unites with iron to form a stable ferrous sulfide, FeS . The combination of the two sulfides, known as matte, collects in the lower area of the furnace and is removed. Such mattes may contain from 15 to 50 percent copper, with a 40 to 45 percent copper content being most common. Mattes may also contain impurities such as sulfur, antimony, arsenic, iron, and precious metals.

The remainder of the molten mass containing most of the other impurities is known as slag. Slag is of lower specific gravity, floats on top of the matte, and is drawn off and discarded. Slags in copper smelting are ideally represented by the composition $2\text{FeO} \cdot \text{SiO}_2$, but contain alumina from the various charge materials and calcium oxide which is added for fluidity. Since slags are discarded, the copper contained in the slag is a major source of copper loss in pyrometallurgical practice. Copper concentration in the slag increases with increasing matte grade. This behavior limits the matte grades normally obtained in conventional practice to below 50 percent copper.

Currently, conventional reverberatory furnaces are used at 11 of the 15 existing primary copper smelters. Two smelters employ electric furnaces, while one smelter employs the Outokumpu flash furnace and another a Noranda continuous smelter. Two smelters will be modifying one or more of their reverberatory furnaces to convert them to oxygen-sprinkle smelting, while two more are planning to retire their reverberatory furnaces within the next few years and install Inco flash smelting furnaces. In a reverberatory furnace (Figure 2-4), fossil fuels such as oil or natural gas are burned above the copper concentrates being smelted. The furnace is a long, rectangular structure, generally about 11 m (36 ft) in width and 40 m (131 ft) in length, with an arched roof and burners at one end. Flames from the burners may extend half the length of the furnace. Temperatures at the firing end of the furnace exceed $1,500^\circ\text{C}$ ($2,730^\circ\text{F}$). Part of the heat in the

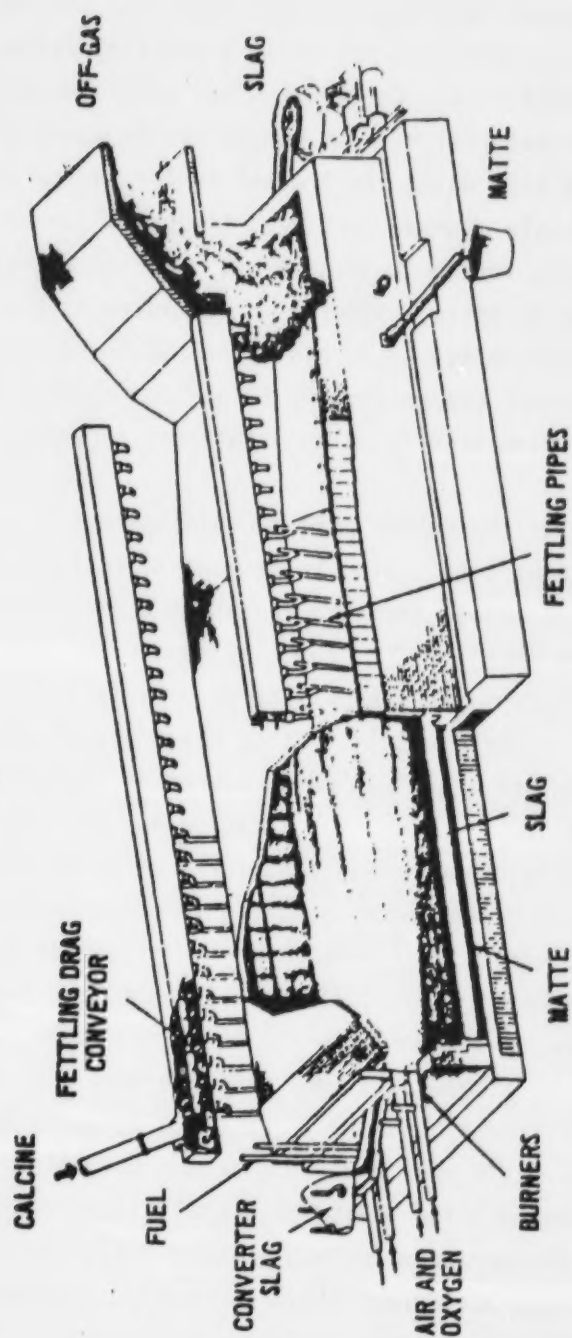


Figure 2-4. Reverberatory Smelting Furnace

combustion gas radiates directly to the charge lying on the hearth below, while a substantial part radiates to the furnace roofs and walls and is reflected down to the charge. The roofs of the older reverberatory furnaces are sprung-arch silica roofs, while almost all newer furnaces have suspended roofs of basic refractory.

Over the years, two types of reverberatory furnaces have evolved, each with its own specific charging methods. The older type is the deep bath reverberatory furnace which contains a large quantity of molten slag and matte at all times. In modern, deep bath reverberatory furnaces, the molten material is held in a refractory crucible with cooling water jackets along the sides, which greatly diminishes the danger of a breakout of the liquid material. In deep bath smelting, several methods exist for charging. Wet concentrates can be charged using slinger belts (high-speed conveyors) that spread the concentrates on the surface of the molten bath. Dry concentrates or calcines from the roaster can be charged through the roof or via a Wagstaff gun (an inclined tube). Roof charging (side charging) is rarely practiced in conjunction with deep bath smelting because of dusting problems with fine dry calcine and explosion potential with green charge. Wagstaff guns minimize these problems and are commonly used.

Side or roof charging is usually used with green charge. With the charge dropped through a series of feed holes in the arch near the walls, a buildup of material forming banks results. The banks slowly melt and serve as protection to the side walls, eliminating the requirement for special cooling.

Combustion gases contain from 15 to 45 percent of the sulfur in the original charge depending primarily upon whether or not the concentrate was roasted. However, because of the high volume of combustion air, SO_2 concentrations are low, with averages varying from 0.5 to 2.0 percent.¹⁵ These lean SO_2 mixtures, unlike offgases from fluid-bed roasters, converters, and other types of smelting furnaces, cannot be economically utilized as feed for sulfuric acid plants.

Electric smelting furnaces provide the heat necessary for smelting copper ore concentrates by allowing carbon electrodes to come into contact with the molten bath within the furnace. The electrodes dip into the slag layer of the bath, forming an electrical circuit. When

an electric current is passed through this circuit, the slag resists its passage, generating heat and producing smelting temperatures. Charge concentrates and fluxing materials are fed through the roof, and a layer of unsmelted charge covers the molten bath. Heat is transferred from the hot slag to the charge floating on its surface, and as the copper concentrates and fluxes are smelted, they settle into the bath forming slag and matte. The chemical and physical changes occurring in the molten bath are similar to those occurring in the molten bath of a reverberatory furnace.

In flash smelting, copper sulfide ore concentrates are smelted by burning a portion of the iron and sulfur contained in the concentrates while they are suspended in an oxidizing environment. As such, the process is quite similar to the combustion of pulverized coal. The concentrates and fluxes are injected with preheated air, oxygen-enriched air, or even pure oxygen, into a furnace of special design. Then, smelting temperatures are attained as a result of the heat released by the rapid, flash combustion of iron and sulfur. Flash smelting technology has been developed by two companies: International Nickel Company (INCO) in Canada and Outokumpu Oy in Finland. The major difference between the two technologies is in the design of the smelting furnace and the oxidizing environment within the furnace. The INCO furnace uses pure oxygen, while the Outokumpu furnace employs preheated air or oxygen-enriched air as the oxidizing medium.

Two smelters are currently planning to convert one or more of their reverberatory furnaces to oxygen-sprinkle smelting. In essence, this conversion will allow the existing reverberatory furnaces to behave like flash furnaces. Specially designed burners positioned on the furnace roof are used to introduce and disperse a mixture of primarily dried concentrates and oxygen. The heat required for smelting is generated from the flash combustion of the sulfur in the mixture. The result is an increase in furnace efficiency and the production of a strong SO_2 gas stream capable of being treated in a sulfuric acid plant.

2.1.2.3 Converting. Matte produced in the reverberatory furnace is transferred in ladles to the converters using overhead cranes. Fourteen of the 15 smelters use converters of the cylindrical Pierce-Smith

type, the most common size being 4 by 9 m (13 by 30 ft). Figure 2-5 is a sketch of a Pierce-Smith copper converter. An alternative to the Pierce-Smith converter is the newer Hoboken or "siphon" converter. The Hoboken converter, currently used by one of the domestic smelters, is essentially the same as the Pierce-Smith converter except that it is fitted with a side flue located at one end of the converter and shaped as an inverted U. This flue arrangement permits siphoning of the converter gases from the interior of the converter, using variable-speed fans and dampers, directly to the offgas collection system. By maintaining a slightly negative pressure at the converter mouth, it is possible to minimize or eliminate emissions. Problems in improper draft at the converter mouth have been reported by Inspiration Consolidated Copper Company, the only domestic user of Hoboken converters. One of the five Hoboken converters operated by Inspiration has been modified to eliminate the siphon area. The modification has resulted in improved performance, and Inspiration intends to modify its four remaining converters in similar fashion.¹⁶

In both Pierce-Smith and Hoboken converters, air is blown from the side through a series of openings called tuyeres. During the initial blowing period (the slag blow), FeS in the matte is preferentially oxidized to FeO and Fe_3O_4 , and sulfur is removed with the offgases as SO_2 . Flux is added to the converter to combine with iron oxide and forms a fluid iron silicate slag. When all the iron is oxidized, the slag is skimmed and poured off from the furnace at various times during slag formation, leaving behind "white metal" or molten Cu_2S .

During this stage, fresh matte is charged into the converter, and the slag blowing continues until a sufficient quantity of white metal has accumulated. When this happens, the white metal is oxidized with air to blister copper during the "copper blow." The blister copper is removed from the converter and cast or subjected to additional fire refining prior to casting. Converter blowing rates can vary between 340 and 855 normal m^3/min (12,000 to 30,000 scfm) of air.

In general practice, the matte is added to the converter in two to six steps, each step followed by oxidation of much of the FeS from the charge. The resulting slag is poured from the converter after

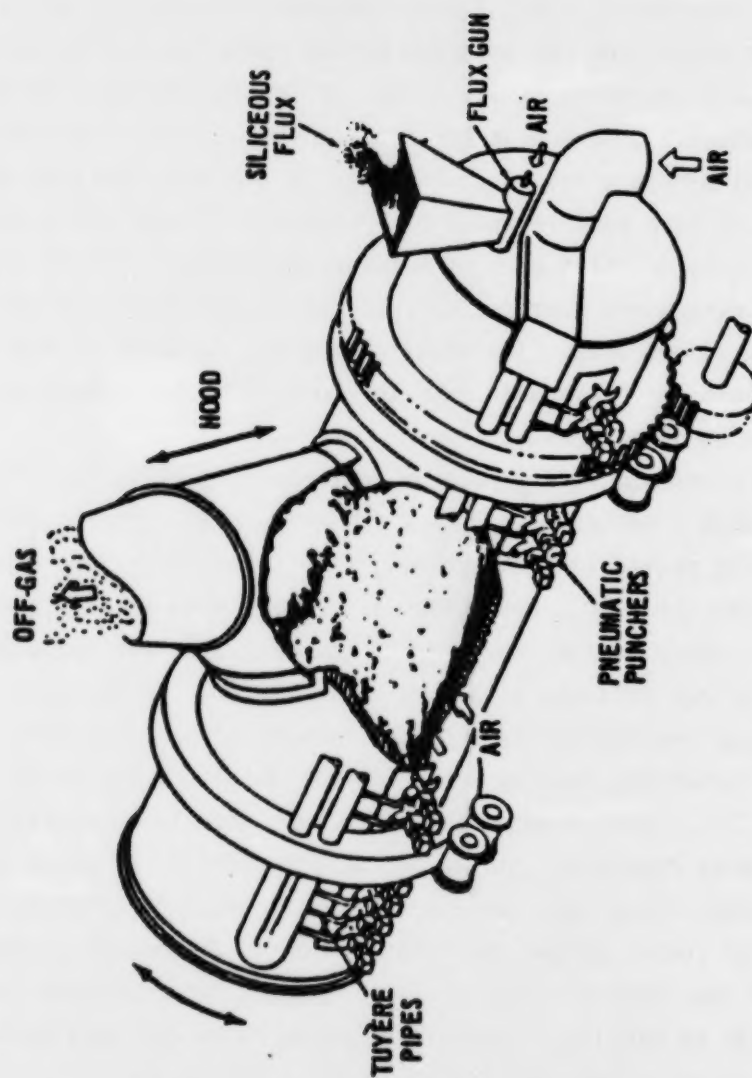


Figure 2-5. Copper Converter

each oxidation step, and a new matte addition is made. In this way, the amount of copper (as matte) in the converter gradually increases until there is a sufficient amount for a final copper-making "blow." At this point, the FeS in the matte is blown down to about 1 percent, a final slag is removed, and the resulting white metal (impure Cu_2S) is oxidized to blister copper. The converting process is terminated when copper oxide begins to appear with the liquid copper. The offgas flow rate leaving the primary head of converters typically ranges from 850 to 1,260 Nm^3/min (30,000 to 45,000 scfm). The average SO_2 concentration in these gases is normally in the range of 4 to 5 percent during the slag blow and 7 to 8 percent during the copper blow. Values of the overall average SO_2 concentration in the offgases (after gas cleaning) from existing domestic converting operations fall in the range of 1.6 to 6.5 percent on a dry basis. The industry-wide average value, as weighted by the respective plant flow rates, is 4.6 percent.¹⁷

2.1.2.4 Refining. Virtually all copper produced by matte smelting is subsequently electrolytically refined. For this reason, the final liquid copper product of the smelter must be suitable for the casting of strong, thin anodes. In a majority of cases, anode copper is fire refined directly from molten blister copper.

Fire refining is performed in rotary-type refining furnaces resembling Pierce-Smith converters or in small hearth furnaces. The rotary-type predominates when molten blister copper is treated directly, while hearth furnaces are used when melting of solid charges is practiced. The temperature of operation is about 1,130 to 1,150°C, which provides sufficient superheat for the subsequent casting of anodes. There is very little heat produced by refining reactions, and some combustion of fuel is necessary to maintain the temperature in the furnace.

Dimensions of the rotary-type refining furnaces vary; however, a 4 by 9 m (13 by 30 ft) furnace may be regarded as typical. Gas flow rates are generally low so as to accurately control the metal composition. Gas pressures at the tuyeres are near 250 to 600 kPa (2.5 to 6 atm). Refining a 250-ton charge of copper requires 3 to 5 hours: 1/2 to 1 hour for the oxidation step, and the remainder for the deoxidation ("poling") step.

A typical sequence of events in rotary anode furnace refining is:

1. Molten blister copper is added to the anode furnace as it becomes available from the converters until about 150 to 300 Mg (165 to 331 tons) have been accumulated;
2. The accumulated charge is then oxidized by blowing air through the tuyeres until the sulfur content is lowered to 0.001 to 0.003 percent S, at which time a small ingot sample of copper shows a slight contraction or small hole; and at which time the oxygen level in the copper is about 0.6 percent;
3. The oxygen is then removed from the copper by blowing natural gas, reformed natural gas, or propane through the tuyeres. The oxygen level in the anode copper is 0.005 to 0.2 percent after this operation, which gives a "flat set" to the anodes when they are cast. The correct "end point" is determined by casting a sample of the copper (which should set to a flat surface) or by continuously analyzing for oxygen with an oxygen probe;
4. Finally, the liquid metal may be covered with low sulfur coke to prevent reoxidation of the copper.

Several older modifications of this process are still being used in which the air is introduced via steel lances, and in which the oxygen-removal step is performed by lowering large logs or poles of green wood into the copper (thereby providing the necessary hydrocarbons). Both of these steps are clumsy, and are being discontinued.

Similarly, the use of the hearth type of anode furnace has by and large been discontinued except where scrap (including anode scrap) and/or blister copper are melted. A typical anode hearth furnace resembles a small reverberatory furnace [width 5 m (16 ft), length 15 m (49 ft), height 3 m (10 ft), inside dimensions] capable of holding 300 Mg (331 tons) of copper. In hearth furnaces, the air and hydrocarbons are introduced into the copper by submerging steel lances into the molten bath. Wood poles are often used for the oxygen removal step.

Since this study analyzes 14 model plants representing the 14 existing low-arsenic throughput copper smelters, plant-by-plant descriptions of operating and emission control parameters are presented in Section 4.3.2 of this document.

2.2 ARSENIC BEHAVIOR AND DISTRIBUTION IN COPPER SMELTERS

Arsenic elimination during copper smelting occurs primarily by volatilization and slagging. The bulk of the arsenic is volatilized in most pyrometallurgical processes and removed with the offgases. In the presence of oxygen, elemental arsenic or arsenic sulfides oxidize to arsenic trioxide which is extremely volatile. However, in an oxidizing atmosphere, the arsenic trioxide (As_2O_3) may oxidize to the higher oxide (As_2O_5) which is less volatile and forms stable nonvolatile arsenates with other metallic oxides.

The elimination of arsenic by slagging is dependent upon the concentration or partial pressure of the arsenic trioxide.¹⁸ If the partial pressure of the oxide is sufficient to allow it to penetrate the slag layer and thus escape, volatilization will occur. However, if the partial pressure is not large enough to allow passage through the slag layer, the arsenic will be mechanically bound in the slag and thus be eliminated on slag disposal. The magnitude of the partial pressure is dependent upon the amount of arsenic present in the process streams.

2.2.1 Arsenic Behavior During Roasting. Arsenic elimination during roasting is indirectly dependent upon the grade of matte required during smelting in the furnace. This requirement limits sulfur elimination during the roasting operation to establish the matte controlling sulfur-to-copper ratio for the calcine feed to the smelting furnace. Arsenic elimination during the roasting process is by volatilization and, therefore, is dependent upon the amount or degree of roasting.

As previously described, the roasting operation is primarily one of oxidation of solid material by means of oxidizing gases. The sulfides present in the copper ore that are oxidized include arsenic sulfides such as FeAs_2S_3 , As_2S_3 , and As_2S_5 . The As_2S_3 boils at 707°C ($1,305^\circ\text{F}$) and As_2S_5 sublims at 500°C (934°F) with decomposition. Arsenic trioxide sublims at 457°C (855°F) and melts at 310°C (590°F). Thus, if the solids are heated to above 700°C ($1,290^\circ\text{F}$), the volatilization of arsenic would seem to be assured, but such a high temperature is not practical. At the beginning of roasting, when there is a large portion of easily fusible sulfides present, high temperature melts the particles which effectively reduces the surface-to-volume ratio available

for sulfur elimination. However, if a low temperature is maintained throughout the entire roasting period, sulfates of metal would form, since the heat of formation of sulfates is higher than that of the corresponding oxides.¹⁹ This would decrease the elimination of sulfur. To minimize the formation of sulfates, it is desirable to maintain a higher temperature (up to 554°C or 1,000°F) at the end of the roast than at the beginning. The ideal temperature condition would therefore be low initially and increase gradually during roasting.

Conditions for the removal of arsenic differ from those of sulfur elimination. Maximum removal of arsenic occurs at a low temperature (500° to 600°C or 930 to 1,110°F) under reducing conditions (when sulfide concentrates are roasted). A higher temperature oxidizing roast causes the formation of arsenic pentoxide, which can react with calcium or iron to form stable and nonvolatile arsenates which remain in the calcine. However, an oxidizing roast is required for the sulfur removal. It is therefore desirable to alternate oxidation and reduction several times to maximize the volatilization of arsenic.

Arsenic elimination in the multi-hearth roaster tends to be greater than in a fluidized-bed unit for any given degree of sulfur elimination. In a multi-hearth roaster, it is possible to vary oxidizing and reducing conditions, temperature, and gas composition on each hearth. The residence times of concentrate particles in a multi-hearth roaster generally range from 1 to 2 hours. The fluidized-bed roaster can provide only one set of conditions at a time, either oxidizing or reducing. The temperature remains constant throughout the bed, and there are a minimum of hot spots or uncontrolled variations in conditions. The residence time of concentrate particles in the fluidized-bed roaster is much smaller compared to a multi-hearth roaster.

Table 2-4 lists data from various sources on the amount of arsenic volatilized on a 100 percent input basis in multi-hearth and fluidized-bed roasters. The elimination of arsenic in the roasting of copper ores and concentrates depends to a considerable extent upon the type of roasting unit used. The third data point indicates that in multi-hearth roasters, as much as 70 to 90 percent arsenic can be driven off when a moderate air consumption rate is used. When concentrates are roasted

Table 2-4. ARSENIC ELIMINATION IN ROASTERS

Type of Roaster	Percent Arsenic in Feed	Percent of Arsenic in Feed Volatilized
1. Multi-hearth roaster ^a	3.8	25
2. Multi-hearth roaster ^b	.22	27
3. Multi-hearth roaster ^c	N.A.	70 - 90
4. Multi-hearth roaster ^d	0.01 - 0.15	5 - 30
5. Fluid-bed roaster ^d	.20	4 - 10
6. Fluid-bed roaster ^e	0.99	60 - 65
7. Fluid-bed roaster ^c	N.A.	15 - 50
8. Fluid-bed roaster ^f	0.02	15

N.A. - Not Available

^aInformation received on the ASARCO-Tacoma smelter from Mr. K.W. Nelson, ASARCO, Incorporated, March 17, 1976.

^bInformation on ASARCO-El Paso obtained from EPA testing (refer to Appendix C).

^cRozlovskii, A.A., "Behavior of Arsenic in the Production of Nonferrous Metals," Tsvetenye Metally/Nonferrous Metals, NO. UDC 669.778.

^dStankovic, D., "Air Pollution caused by Copper Metallurgy Assemblies in Bor," Institute for Copper, Bor, Project No. 02-513-1, U.S. EPA.

^eInformation on Anaconda obtained from Mr. Richard Sloane, Director of Technology, Anaconda Company, October 11, 1978.

^fInformation on Kennecott-Hayden received from Mr. I.G. Pickering, Vice President, Environmental Affairs, Kennecott Copper Corporation, May 9, 1978.

in fluidized-bed roasters (seventh data point) with a great excess of air, as little as 15 to 50 percent of the arsenic is eliminated. The fourth and fifth data points also indicate that arsenic elimination in multi-hearth roasters (5 to 30 percent) is greater than in fluidized-bed roasters (4 to 10 percent). However, the amount of arsenic volatilized is dependent upon the amount of roasting done or allowable, since ASARCO-Tacoma using a "high" arsenic feed eliminates only 25 percent of the arsenic in the feed, although more arsenic elimination is possible. This, as ASARCO has pointed out, is due to the production of low grade matte which is essential for the removal of impurities during the converting operation.²⁰ A relatively low grade matte leads to higher converter temperatures which are essential for the vaporization of impurities in the converter. Also, low grade matte tends to increase the blowing time or "sweep" in the converter which facilitates impurity elimination. Conversely, in the fluidized-bed roaster at the formerly operated Anaconda smelter (sixth data point in Table 2-4), between 60 and 65 percent of input arsenic was volatilized. This was due to the longer roast performed at Anaconda which also eliminated a large amount of sulfur in the feed. Consequently, a high grade matte (50 percent) is produced in the electric furnace.

2.2.2 Arsenic Behavior in Smelting Furnaces

Arsenic elimination in smelting furnaces is by volatilization and slagging. Arsenic behavior in the smelting furnace is controlled by the fact that smelting occurs in the presence of copper. As has long been known, and confirmed by recent thermodynamic data,^{21,22} arsenic is more stable in copper than in Cu_2S , with a decrease in its thermodynamic activity and, hence, volatility. As a result, in the smelting furnace the volatility of arsenic will change with the grade of matte being produced.

Since volatilization plays a major role in the elimination of As during the production of matte in smelting furnaces, any factors which enhance volatilization will further improve its elimination. These are:

- Mineralization: some As compounds have higher vapor pressures than others and will therefore volatilize to a greater degree.

- Green charge or calcine charge: a calcine charge will have the more-easily volatilized As compounds removed in roasting; thus, for a given original mineralization, a green-charged furnace should volatilize a greater proportion of the As.
- Smelting temperature: the higher the temperature, the greater the degree of volatilization.
- Exposure of slag surface free to charge material cover: the greater the exposure, the greater the volatilization of As from the slag.

The amount of arsenic slagged or volatilized differs from one furnace to another. The behavior of arsenic in the different types of furnaces is described in the following sections.

2.2.2.1 Reverberatory Furnaces. The arsenic input into the reverberatory furnace is from the arsenic in the new charge, slag returned from the converters, and recycled dusts and reverts. This arsenic is eliminated by either volatilization or slagging. The amount of arsenic slagged or volatilized differs from one smelter to another, as indicated in Table 2-5.

Data presented in Table 2-5 have been organized in two groups. Group A represents those furnaces which have a concentration of arsenic of greater than 0.2 percent in the feed. Group B represents smelters having a smelter feed with less than 0.2 percent arsenic content. All percentages presented in Table 2-5 are on a 100 percent input basis in the furnace.

Examining the data in Group A from ASARCO-Tacoma,²³ ASARCO-EI Paso,²⁴ Phelps Dodge-Ajo,²⁵ and Anaconda²⁶ (these data are for the old Anaconda smelting configuration having a green reverberatory furnace), the amount of arsenic volatilized and leaving the gas phase ranges from 55 to 75 percent. However, all of these smelters have greater than 0.2 percent arsenic in the feed. The ASARCO-Tacoma and ASARCO-EI Paso smelters feed roasted calcine into their reverberatory furnaces but still have high volatilization. This is because only 25 percent of the arsenic is volatilized in the roaster at the ASARCO smelters. The charge to the reverberatory furnace is therefore still high in arsenic content.

Table 2-5. ELIMINATION OF ARSENIC IN REVERBERATORY FURNACES
(100 percent input basis)

Type of Feed	Percent Arsenic in Feed	Percent Arsenic Eliminated by	
		Volatilization	Slagging
Calcine ^a Group A	3.8	69	13
Calcine ^b	0.22	62	20
Green ^c	0.3	55	25
Green ^d	0.81	73	10
Green ^e	0-2	70-90	5-15
Calcine ^e	0-2	15-70	26-60
Calcine ^f Group B	0.02	37	16
Calcine ^g	0.01-0.2	5-30	35-55
Green ^h	0.13	29	26
Calcine ⁱ	N.A.	12	54
Green ^j	0.0035		51

N.A. - Not Available

NOTE: The percent arsenic content in calcine feed to the smelting furnace is not known. The concentrations listed above are for the feed into the roaster and do not represent arsenic concentration in the calcine.

^aInformation received on ASARCO-Tacoma from Mr. K.W. Nelson of ASARCO, Incorporated, March 17, 1976.

^bInformation obtained from testing at ASARCO-El Paso (refer to Appendix C).

^cSchwitzgebel, K., et al., "Trace Element Study at a Primary Copper Smelter," Prepublication copy, EPA Contract Number 68-01-4136, January 1978.

^d"The Proposed Arsenic Standard: Feasibility and Estimated Costs of Compliance for Three U.S. Copper Smelters," prepared by D.B. Associates for OSHA Contract B-9-F-5-1663, March 25, 1976.

^eRozlovskii, A.A., "Behavior of Arsenic in the Production of Nonferrous Metals," Tsvetnye Metally/Nonferrous Metals No. UDC 669.778.

^fInformation on Kennecott-Hayden received from Mr. I.G. Pickering, Vice President, Environmental Affairs, Kennecott Copper Corporation, May 9, 1978.

^gStankovic, D., "Air Pollution Caused by Copper Metallurgy Assemblies in Bor," Institute for Copper, Bor, Project No. 02-513-1, U.S. EPA.

^hInformation received from Mr. Hank Hansen of Kennecott Copper Corporation on the old Kennecott-Utah smelter.

ⁱRuddle, R.W., "The Physical Chemistry of Copper Smelting," Institute of Mining and Metallurgy, London, 1953.

^jTurnbull, D.L., "Converter Practice at Mufulira," Seventh Commonwealth Mining and Metallurgical Congress, 1961.

The data obtained in Group B from Kennecott-Hayden,²⁷ Bor-Yugoslavia,²⁸ Kennecott-Utah²⁹ (for the old smelter configuration utilizing the reverberatory furnace), and the information obtained by Ruddle³⁰ indicate that the amount of arsenic volatilized and leaving in the gas phase ranges from 5 to 27 percent. Also, the total elimination in the furnace ranges from 40 to 60 percent of the input arsenic. This is reaffirmed by the Mufulira data.³¹ However, the aforementioned smelters have less than 0.2 percent arsenic in the feed.

This leads to two basic observations for the reverberatory furnace:

1. With greater than 0.2 percent arsenic in the feed, 55 to 75 percent of the arsenic generally leaves in the gas phase and 10 to 25 percent is slagged out.
2. With less than 0.2 percent arsenic in the feed, 5 to 37 percent of the arsenic generally leaves in the gas phase and 16 to 55 percent is slagged out.

The aforementioned observations are consistent with those reported in the U.S.S.R.³² (Group A) where the amount of arsenic volatilized was lower for roasted feed (15 to 70 percent volatilized) since it has low-arsenic content, as compared to unroasted feed (70 to 90 percent volatilized) which has higher arsenic content. The amount of arsenic eliminated by slagging ranged from 25 to 60 percent for roasted feed and 5 to 15 percent for unroasted feed.

2.2.2.2 Electric Furnaces. Table 2-6 summarizes the available information on arsenic elimination in electric furnaces. Paulson et al.,³³ used calcine from the ASARCO-Tacoma smelter and ran tests on a laboratory electric furnace. They found the behavior of arsenic to be similar to that in the reverberatory furnace. However, some questions remain regarding the manner in which these smelting tests were performed. In actual practice, copper smelting electric furnaces are operated with a cold top - that is, a layer of solid charge is maintained over the entire surface of the melt at all times. Paulson et al., carried out their tests with the molten slag surface uncovered by the charge material. In the latter case, the slag is hotter, and all the arsenic vaporized from it will leave with the flue gases rather than be recondensed when passing through the relatively cold charge layer.

Table 2-6. ELIMINATION OF ARSENIC IN ELECTRIC FURNACES
(100 percent input basis)

Type of Furnace	Type of Feed	Percent Arsenic in Feed	Percent Arsenic Eliminated by	
			Volatilization	Slagging
Electric ^a	Calcine	3.8	38.3-68.2	1.5-11.2
Electric ^b	Calcine	0.99	8	78
Electric ^c	Calcine	1.8	24	50.5

NOTE: The percentage of arsenic content in calcine feed to the smelting furnace is not known. The concentrations listed above are for the feed into the roaster and do not represent arsenic concentration in the calcine.

^aPaulson, D.L., et al., "Smelting of Arseniferous Copper Concentrate in an Electric Arc Furnace," United States Bureau of Mines Report of Investigation 8144, 1976.

^bInformation received on the Anaconda smelter from Mr. Richard Sloan, Director of Technology, Anaconda Company, October 11, 1978.

^c"Economic Impact of New Source Performance Standards on the Primary Copper Industry: An Assessment," Final Report to U.S. Environmental Protection Agency, EPA Contract No. 68-02-1349, October 1974.

2.2.2.3 Flash Furnaces - The Noranda reactor flash smelting furnace has been introduced by Kennecott at their Utah smelter. In this process, copper concentrates and flux are fed into a horizontal cylindrical reactor where smelting and converting occurs under the dynamic action of oxygen-enriched air introduced through tuyeres below the bath. Heat for smelting is provided by exothermic converting reactions supplemented by burners. As indicated by Mackey et al.,³⁴ the elimination of As in the Noranda process is more favorable at lower matte grades. The amount of arsenic volatilized is much greater under Noranda matte-making conditions compared to arsenic volatilized under regular copper-production conditions. Also, the amount of arsenic reporting in the matte is much lower.

Table 2-7 shows that the amount of arsenic volatilized from four different flash furnaces is near 76 to 85 percent, and the amount slagged ranges from 7 to 17 percent.

2.2.3. Arsenic Behavior During Converting

Arsenic distribution in a copper converter between gases and slag varies widely, as shown in Table 2-8. When a high grade matte is converted, metallic copper appears early in the cycle and acts as a collector for arsenic because arsenic is more stable and less volatile in metallic copper than in copper sulfide. Depending upon the matte grade, as much as 70 percent of the arsenic may report in the blister copper, and only 30 percent is eliminated by volatilization or slagging.³⁵ When a low grade matte is converted, the formation of metallic copper is delayed, and a much larger proportion of the arsenic is eliminated. Up to 92 percent^{36,37} of the arsenic will be volatilized in such cases. In normal practice, it is neither that low nor that high; approximately 70 percent of the arsenic is volatilized in the converter, and nearly 16 percent reports in the slag.

In some domestic copper smelters such as ASARCO-El Paso, it is common to recycle low grade secondary materials and copper precipitates. If materials to be smelted have high impurity content (particularly lead speiss or other recycled materials), a low grade matte is necessary to produce sufficient heat for elimination of these materials. Decreasing matte grade allows time for the volatilization of impurities since the slagging cycle increases with lower matte grade. Also, the longer

Table 2-7. ELIMINATION OF ARSENIC IN FLASH FURNACES
(100 percent input basis)

Type of Furnace	Type of Feed	Percent Arsenic in Feed	Percent Arsenic Eliminated by	
			Volatilization	Slagging
Noranda ^a Reactor	Green	0.06	85	7
"KCS" ^b Process	Green	N.A.	79	11
Noranda ^c Reactor	Green	0.14	82	13
Otokumpu ^d	Green	0.17	76	17

N.A. - Not Available

^aHackey, P.J., et al., "Minor Elements in the Noranda Process," Paper presented at the 104th Annual AIME Meeting, New York, February 16-20, 1975.

^bGeorge, D.B., et al., "Minor Element Behavior in Copper Smelting and Converting," Joint AIME-MMIJ Conference, 1976.

^cInformation on Kennecott-Garfield received from Mr. I.G. Pickering, Vice President, Environmental Affairs, Kennecott Copper Corporation, May 9, 1978.

^dKoh, Shiroh, "Extractive Metallurgy of Kuroko," Paper presented at the joint meeting of the MMIJ-AIME, Tokyo, May 24-27, 1972.

Table 2-8. ELIMINATION OF ARSENIC DURING CONVERTING
(100 percent input basis)

Type of Matte Producing Furnace	Percent Cu in Matte	Percent Arsenic Eliminated by	
		Volatilization	Slagging
Reverberatory ^a	N.A.	73.0	11.0
Reverberatory ^b	40	92.0	0
Reverberatory ^c	40	92.0	5.0
Reverberatory ^d	35-55	76.0	19.0
Reverberatory ^e	N.A.	50-85	10-35
Reverberatory ^f	35-55	55.0	23.0
Outokumpu Flash ^g	45	43.0	29.0
KCS Smelting			
Converter ^h	70	73.0	0
Shaft Furnace ⁱ	N.A.	70.2	29.5

N.A. - Not Available

^aRuddle R.W., "The Physical Chemistry of Copper Smelting," Institute of Mining and Metallurgy, London, 1953.

^bInformation received on ASARCO-Tacoma from Mr. K.W. Nelson, ASARCO, Incorporated, March 17, 1976.

^cInformation obtained from tests performed at ASARCO-El Paso (refer to Appendix C).

^dStankovic, D., "Air Pollution Caused by Copper Metallurgy Assemblies in Bor," Institute for Copper, Bor, Project No. 02-513-1, U.S. EPA.

^eRozlovskii, A.A., "Behavior of Arsenic in the Production of Nonferrous Metals, "Tsvetnye Metally/Nonferrous Metals, Number UDC 669.778.

^fSchwitzgebel, K., et al., "Trace Element Study at a Primary Copper Smelter," Prepublication copy, EPA Contract Number 68-01-4136, January 1978.

^gKoh, Shiroh, "Extractive Metallurgy of Kuroko," Paper presented at the joint meeting of the MMIJ-AIME, Tokyo, May 24-27, 1972.

^hGeorge, D.B., et al., "Minor Element Behavior in Copper Smelting and Converting," Joing AIME-MMIJ Conference, 1976.

ⁱInformation received from Technika, Sofia, Bulgaria, September 24, 1978.

converting time allows a greater duration of gas sweep across the bath for impurity removal. Hence, the concentration of matte grade governs the recycle of intermediates in the converter.

2.2.4 Arsenic Balance

There is a wide variation in the distribution of arsenic among the various products of a particular process from one low-arsenic throughput smelter to another. This is due not only to the difference in feed composition but also to factors such as temperature, blowing rates, gas composition, and the analysis and relative quantities of products. The data presented in Tables 2-5, 2-6, 2-7, and 2-8 are summarized in Table 2-9 on a 100 percent input basis through the smelting circuit. Table 2-9 shows that the wide variation in arsenic elimination exists not only for different smelter configurations but also for smelters having similar circuits. Detailed causes of these variations are complex, and relatively little information can be found in the literature. There are, however, relationships between process parameters that affect arsenic and other minor element distributions that can be observed from the data in Table 2-9.

The distribution of arsenic within the various smelting processes is specifically controlled by the characteristics of the arsenic and its environment. There appear to be two fairly distinct input levels of arsenic which result in different distributions. Referring to Table 2-9, it can be seen that for smelting processes with levels of input arsenic greater than or equal to 0.2 or 0.3 percent, the resulting arsenic distribution appears to be directly influenced by temperature and the presence of copper. The copper tends to fix the arsenic. The partial pressure of the arsenic trioxide is high enough to allow volatilization of the arsenic through the slag layer in the smelting furnace. This results in a lower proportion of the input arsenic leaving with the slag. However, when the level of input arsenic is less than 0.2 percent, the data in Table 2-9 indicate that a higher proportion of the input arsenic is transferred to the slag. The hypothesis is that in the case of lower arsenic input, the arsenic is mechanically bound or locked into the feed, and therefore, not readily released. This prevents it from being volatilized and tends to allow it to enter the slag.

Table 2-9. ARSENIC BALANCE —
WEIGHT PERCENT AS REPORTING IN SMELTER PRODUCTS (AMOUNT INPUT = 100)

PROCESSES	Input in smelter feed		Roasting		Smelting		Converting		Blister
	Wt. % As in charge	% As volatilized	% As volatilized	% As slagged	% As volatilized	% Cu in matte	% As slagged	% As volatilized	% As in copper
Reverberatory - Converters ^a	0.3	N.R.	25.0	55.0	35-45	4.5	11.0	4.5	
Reverberatory - Converters ^b	0.81	N.R.	9.7	73.3	40.0	3.4	11.3	2.3	
Reverberatory - Converters ^c	0.13	N.R.	26	29	40.0	9	32	5	
Reverberatory - Converters ^d	0.0035	N.R.		51	N.A.		49		
Reverberatory - Converters ^e	N.A.	*	54.2	11.8	N.A.	3.75	24.8	5.45	
Multi-hearth - Reverb - Converters ^f	3.8	25.0	10.0	52.0	40.0	0	12.0	1.0	
Multi-hearth - Reverb - Converters ^g	0.22	27.0	15.0	45.0	40.0	0.6	11.5	0.9	
Multi-hearth - Reverb - Converters ^h	0.01-0.15	5-30	30-45	5-15	35-55	5-10	20-40	1.5-3	
Fluidized-Bed - Reverb - Converters ^h	0.2	4-10	35-40	25-30	39-43	0-10	15-20	1-2	
Fluidized-Bed - Reverb - Converters ⁱ	0.02	15	13	31	40	12.1	28.7	0.2	
Fluidized-Bed - Electric - Converters ^j	0.99	63.3	28.9	2.7	50	1.4	3.6	0.1	
Multi-hearth - Electric ^k	3.8	25.0	1.13-8.4	28.73-61.15	40	Experimental study done on a pilot plant			
Multi-hearth - Electric - Converters ^l	1.8	81	8	7.6	36	1.0	1.2	1.2	
Noranda Reactor - Converters ^m	0.06	N.R.	7.0	85.0	70.0	2	4	1	
Noranda Reactor - Converters ⁿ	0.14	N.R.	13.0	82.0	70	0	2.5	2.5	
Pierce-Smith Reactor - Converters ^o (KCS process)	N.A.	N.R.	11.0	79.0	70.0	0	7.3	2.7	
Outokumpu Furnace - Converters ^p	0.17	N.R.	17.0	76.0	45.0	2.0	3.0	2.0	

N.A. - Not Available

N.R. - No Roasting

*The input into the furnace is a calcine feed.

Footnotes for Table 2-9.

- ^aSchwitzgebel, K., et al., "Trace Element Study at a Primary Copper Smelter," Prepublication copy, EPA Contract No. 68-01-4136, January 1978.
- ^bBurton, D.J., "The Proposed Arsenic Standard: Feasibility and Estimated Costs of Compliance for Three U.S. Copper Smelters," prepared for OSHA, Washington, D.C., Contract B-9-F-5-1663, March 25, 1975.
- ^cConversation with Mr. Hank Hansen, Environmental Engineer, Kennecott Copper Corporation, Salt Lake City, Utah, September 26, 1978.
- ^dHerneryd, O., et al., "Copper Smelting in Boliden's Ronnskar Works Described." Journal of Metals, March 1954.
- ^eRuddle, R.W., "The Physical Chemistry of Copper-Smelting," Institute of Mining and Metallurgy, Lond, 1953.
- ^fCorrespondence from Mr. K.W. Nelson, ASARCO, Incorporated to Mr. J. Padgett, Environmental Protection Agency, March 17, 1976.
- ^gHarris, D.L., "Particulate and Arsenic Emission Measurements From a Copper Smelter," Volume I (text), Monsanto Research Corporation, EMB Project Report No. 77-CUS-6, EPA Contract No. 68-02-1404, Task No. 36, 1977.
- ^hStankovic, D., "Air Pollution Caused by Copper Metallurgy Assemblies in Bor," Institute for Copper, Bor, Project No. 02-513-1, U.S. EPA.
- ⁱData for Kennecott-Hayden received in the correspondence from Mr. I.G. Pickering, Vice President Environmental Affairs, Kennecott Copper Corporation, to Mr. D.R. Goodwin, Director, ESED, U.S. EPA, May 9, 1978.
- ^jInformation received on the Anaconda smelter from Mr. Richard Sloan, Director of Technology, Anaconda Company, October 11, 1978.
- ^kPaulson, D.L. et al., "Smelting of Arseniferous Copper Concentration in an Electric-Arc Furnace," United States Bureau of Mines Report of Investigations 8144, 1976.
- ^l"Economic Impact of New Source Performance Standards on the Primary Copper Industry: An Assessment," Final Report to U.S. Environmental Protection Agency, EPA Contract No. 68-02-1349, October 1974.
- ^mMackey, P.J., McKerrow, G.C., Terassoff, P., "Minor Elements in the Noranda Process," Paper presented at the 104th Annual AIME meeting, New York, February 16th - 20th, 1975.
- ⁿData for Kennecott-Hayden received in the correspondence from Mr. I.G. Pickering, Vice President Environmental Affairs, Kennecott Copper Corporation, to Mr. D.R. Goodwin, Director, ESED, U.S. EPA, May 9, 1978.
- ^oGeorge, D.B., Donaldson, J.W., Johnson, R.E., "Minor Element Behavior in Copper Smelting and Converting," 1976 Joint AIME-MMIJ Conference.
- ^pKoh, S., "Extractive Metallurgy of Kuroko," Joint Meeting MMIJ-AIME, Tokyo, May 1972.

While it has been theorized by some that multi-hearth roasters are required to eliminate arsenic, this is not necessarily confirmed by the available information. In general, with the combined processes of the roaster and reverberatory furnaces, it appears that in the case of the multi-hearth roaster, a larger amount of arsenic is volatilized than in the reverberatory furnace. In the case of the fluidized-bed reverberatory furnace combination, less arsenic is volatilized in the fluidized-bed than in the reverberatory furnace. However, if the sum of the roaster and furnace arsenic volatilization is considered, then the total seems to be the same with either type of roaster (refer to eighth and ninth data points in Table 2-9).

2.3 ARSENIC DISTRIBUTION AND EMISSIONS AT DOMESTIC LOW-ARSENIC THROUGHPUT COPPER SMELTERS

Arsenic distributions at domestic copper smelters were determined by using (1) arsenic mass balances supplied by the smelters, (2) the previously cited arsenic distribution information for foreign and domestic copper smelters available in the literature, and (3) control equipment performance data obtained by EPA testing at various U.S. copper smelters. The estimated arsenic distributions for each domestic copper smelter are presented in Appendix F. Complete recycle of the collected flue dusts from the existing control devices at each smelter was assumed in these balances. The arsenic removal efficiency of existing control devices was taken into account in determining the arsenic material balances for 10 of the 14 low-arsenic throughput smelters. For the remaining four smelters, Phelps Dodge-Ajo, -Morenci, ASARCO-Hayden, and Kennecott-Hurley, material balances were generated for the smelter configurations and control equipment arrays projected after completion of modernization programs. The modernization programs for these smelters are discussed in Section 4.2.1.

Arsenic emissions from primary copper smelters can be categorized as process and fugitive emissions. Process emission sources include primary offgas emissions from roasting, smelting, and converting operations. Fugitive emissions include those emissions which escape from process flow streams due to leakage through process exhaust systems, material transfer systems, or ineffective capture at the source of generation.

2.3.1 Process Arsenic Emissions

Information indicating the distribution of arsenic in the smelter circuit was received from most domestic copper smelters. Based on this information, arsenic mass balances for each smelter were performed. Typically, the information obtained consisted of process material balances and estimates or measurements of the arsenic content in these materials. However, the information received was incomplete for a number of copper smelters. In these cases, assumptions were made regarding the behavior of arsenic based on the information presented in Section 2.2 on the behavior of arsenic at copper smelters.

For those smelters for which information on arsenic distribution was not obtained or the information provided was incomplete, an arsenic distribution for the smelter was developed based on the type of smelting configuration at that particular smelter, the level of arsenic input to that smelter, and the availability of arsenic distribution information from smelters having similar configurations. For example, lack of complete arsenic distribution data for the projected configuration of ASARCO-Hayden after installation of an INCO-flash furnace necessitated use of an arsenic balance provided by Kennecott for the projected arsenic distribution at the Hurley smelter after modification to INCO smelting technology.

The control equipment efficiencies used in the arsenic mass balances were based on tests performed at several existing units.^{38,39,40,41} Tests performed on baghouses and electrostatic precipitators have indicated that the collection efficiency of the control equipment for arsenic is dependent upon the inlet temperature of the offgases and the arsenic concentration of the gas stream, and that maximum collection of arsenic trioxide occurs at reduced temperatures. As a result, the collection efficiency can vary from 30 to 99.0 percent. The results obtained are summarized in Table 2-10. Where company-supplied data were not available, an arsenic removal efficiency of 99 percent was ascribed to acid plants, due to the gas precleaning and conditioning required for effective acid plant operation. Detailed test data are available in Appendix C, and a discussion on the performance of these control devices is presented in Section 3.2.1.

Table 2-10. MEASURED ARSENIC COLLECTION EFFICIENCIES
OF CONTROL DEVICES^a

Smelter	Device	Operating Temperature (°C)		Collection Efficiency Percent
		Inlet	Outlet	
Phelps Dodge-Ajo	Reverb ESP	327	313	27.8
ASARCO-El Paso	Roaster & Reverb - Spray Chamber/ESP	212	104	96.2
Anaconda	Spray Chamber/Baghouse	263	101	98.9
Kennecott-Hayden	Venturi Scrubber	329	39	98.3
ASARCO-Tacoma	Roaster Baghouse	91	86	99.7

^aDetailed test data available in Appendix C.

The arsenic distributions for all domestic copper smelters are given in Appendix F. These distributions are based on a full recycle of flue dusts and converter slag (except at Kennecott-Hayden where converter slag is not recycled). In most cases, the final arsenic distributions have been obtained after performing iterative recycles until steady-state conditions are reached. Steady-state conditions are indicated by stabilizing the arsenic content of the blister copper and the converter slag.

The estimated potential process arsenic emissions in the absence of control for each of the domestic low-arsenic throughput copper smelters are summarized in Table 2-11.

2.3.2 Fugitive Arsenic Emissions

Fugitive emissions may be characterized as emissions which escape directly from the process area to the atmosphere rather than through a flue or exhaust system. They result from leakage in and around process equipment and from material handling and transfer operations. These emissions may be considered as low level emissions as compared to process emissions, since they usually leave the smelter at or near ground level, whereas process emissions are discharged through a tall stack.

Listed in Table 2-12 and shown in Figure 2-6 are potential sources of fugitive arsenic emissions. These emissions depend upon the particular types of equipment and operating practices employed by the copper smelter.

2.3.2.1 Roaster.

2.3.2.1.1 Charging. Fugitive emissions during charging of multi-hearth roasters seldom occur because of the water content (8 to 10 percent) in the feed, and the "choke feed" mechanism used on the charging hoppers. Fugitive emissions during charging are seldom emitted from a properly designed and operated fluidized-bed roaster because of the enclosed feed and discharge system.

2.3.2.1.2 Leakage. Fugitive arsenic emissions from multi-hearth roasters may be emitted from leaks that can occur at the doors located at each one of the hearth levels, from holes in the actual shell of the roaster, or from leaks around the shaft that holds the rabble arms. Under normal operating conditions, these emissions are minimized

Table 2-11. SUMMARY OF PROCESS ARSENIC EMISSION ESTIMATES IN
ABSENCE OF CONTROL FOR LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS

Smelter	Emission Source ^a	Exit Gas Arsenic Content kg/hr
ASARCO-El Paso	MHR	86.6
	REV	54.9
	CONV	76.2
ASARCO-Hayden	FF	157.0
	CONV	45.0
Tennessee Chemical Co. - Copperhill	FBR	0.2
	EF	0.4
	CONV	0.5
Inspiration- Miami	EF	4.5
	CONV	1.5
Kennecott-Garfield	NOR	115.0
	CONV	6.0
Kennecott-Hayden	FBR	1.9
	REV	5.3
	CONV	5.0
Kennecott-Hurley	FF	1.3
	CONV	0.4
Kennecott-McGill	REV	18.6
	CONV	35.6
Magma-San Manuel	REV	1.8
	CONV	0.5
Phelps Dodge-Ajo	OXREV	45.3
	CONV	2.3
Phelps Dodge- Douglas	MHR	2.2
	REV	0.9
	CONV	3.2
Phelps Dodge- Hidalgo	FF	13.7
	CONV	0.9
Phelps Dodge- Morenci	OXREV	4.3
	CONV	5.3
Copper Range - White Pine	REV	0.4
	CONV	0.2

^a Sources: MHR - Multihearth Roaster
REV - Reverberatory Furnace
CONV - Converters
FF - Flash Furnace

FBR - Fluid Bed Roaster
EF - Electric Furnace
NOR - Noranda Reactor
OXREV - Oxygen-Sprinkle
Reverberatory Furnace

Table 2-12. POTENTIAL SOURCES OF FUGITIVE
ARSENIC EMISSIONS

Roaster

Charging
Leakage
Hot calcine discharge and transfer

Smelting Furnace

Charging
Leakage
Matte tapping
Slag tapping
Converter slag return

Converters

Charging (matte, reverts, flux, lead smelter by-products, cold
dope)
Blowing (primary hood leaks)
Skimming
Holding
Pouring of slag and blister
Converter leaks

Anode Furnace

Charging
Blowing
Holding
Pouring

Miscellaneous

Dust handling and transfer
Ladles (matte and slag)
Slag dumping

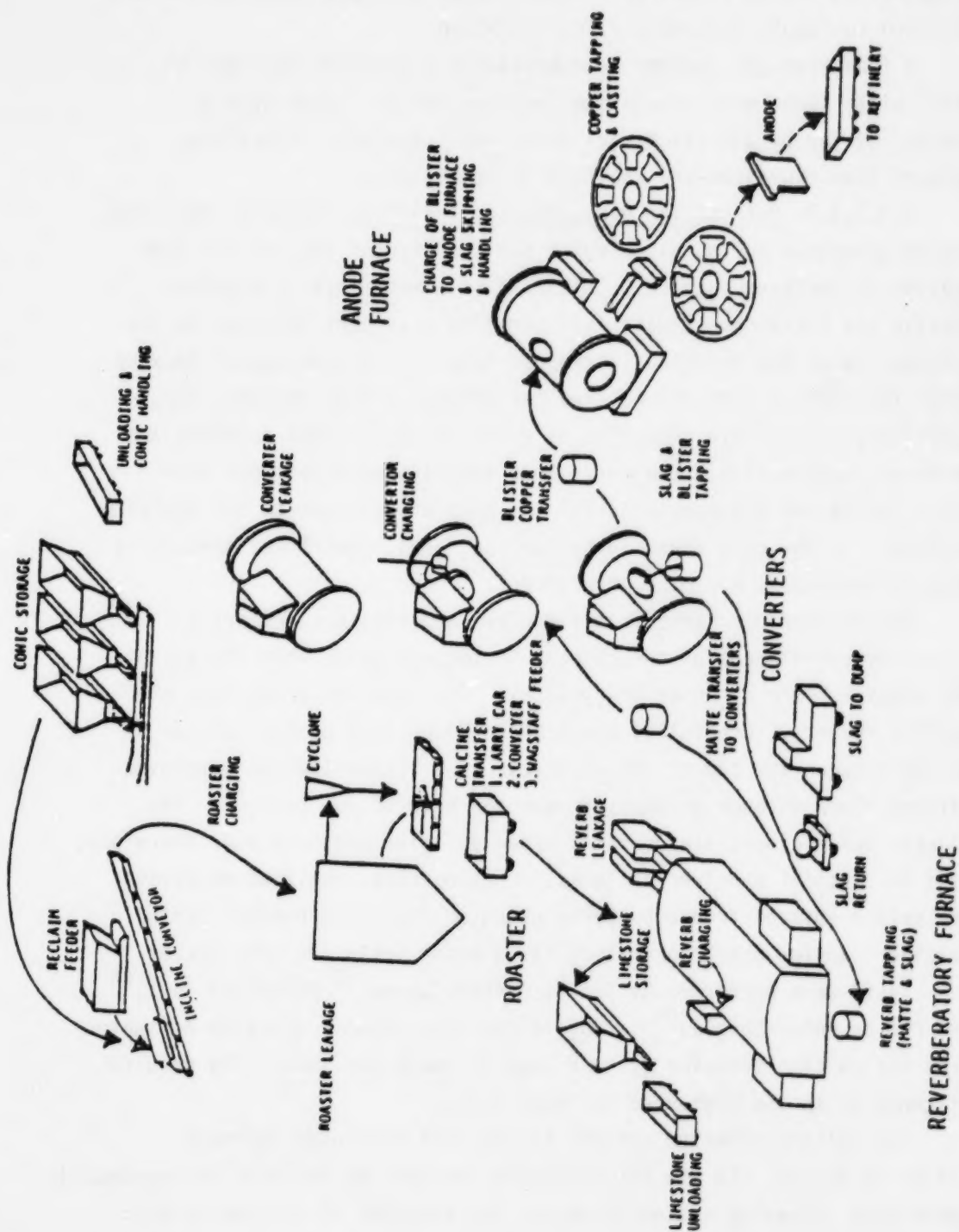


Figure 2-6. Fugitive Emission Sources at Primary Copper Smelters

by operating the multi-hearth roasters under a slight negative pressure required to supply induced air for oxidation.

A fluidized-bed roaster is essentially a vertical cylinder of steel plate lined with insulation and fire bricks. This type of roaster is fed by and discharges into closed systems. Therefore, leakage from fluidized-bed roasters is negligible.

2.3.2.1.3 Hot calcine discharge and transfer. Fugitive emissions may be generated during discharging and transfer of hot calcine from roaster to smelting furnaces. Smelters with multi-hearth roasters usually use larry cars (small rail cars) to transport calcines to the furnace. When the material is dropped from the calcine hopper located under the roaster into the covered car through a feed opening, large quantities of dust are generated as a result of material movement and pressure changes within the car. Some fugitive emissions can also occur during the transportation of the roaster calcines to the smelting furnace. In the case where larry cars are used, their feed opening is usually covered to minimize this effect.

Hot calcine discharge from fluidized-bed roasters primarily occurs by entrainment of the calcine in the gas going from the top of the roasters into a series of cyclones. The material drops into the cyclone hoppers. Generally, about 80 to 85 percent of the calcine passes through the top of the roasters. The "underflow" or remaining calcine flows through an opening near the base of the roaster. The roaster and cyclones are operated under positive pressure and, therefore, must be airtight and free of leaks. Consequently, fugitive emissions are seldom emitted from a properly operated fluid-bed roaster during calcine transfer operations since it is essentially a closed system.

Tests were performed by EPA at ASARCO-Tacoma,⁴² ASARCO-El Paso,⁴³ and Phelps Dodge-Douglas⁴⁴ to obtain fugitive arsenic emission estimates from the calcine transfer systems used at these smelters. The results of these tests are presented in Table 2-13.

The calcine transfer systems in the aforementioned smelters differ in design. At the ASARCO-Tacoma smelter, an enclosed spring-sealed, apron-type unloading system is used. The transfer of calcine in this system is completely enclosed, and a minimum of fugitives are emitted. The calcine transfer systems used at the ASARCO-El Paso and Phelps

Table 2-13. FUGITIVE ARSENIC EMISSIONS DURING CALCINE TRANSFER FROM MULTIEARTH ROASTERS

Smelter	Sample Run	Arsenic in Calcline (lb/hr)	kg/hr	Arsenic Emissions			Comments
				English Units ppm	lb/hr	Metric Units Mg/m ³	
ASARCO-Tacoma	1	719	326	69.7	1.0	217.3	0.46
	2	719	326	109.3	1.7	340.9	0.76
	3	1,073	987	153.6	2.7	479.0	1.24
	Avg.			110.9	1.8	345.7	0.82
ASARCO-EI Paso	1	130	59	3.7	0.33	11.53	0.15
	2	130	59	1.03	0.09	3.23	0.04
	3	130	59	2.5	0.22	7.81	0.10
	Avg.			2.41	0.22	7.52	0.10
Phelps Dodge-Douglas	1	10.5	4.8	0.0	0.007	0.059	0.003
	2	1.0	0.5	0.0	0.026	0.22	0.011
	3	2.3	1.0	0.0	0.064	0.642	0.029
	Avg.			0.0	0.032	0.307	0.014

Dodge-Douglas smelters are, however, not as effective. A description of these systems is provided in Section 3.2.2.2.

Fugitive arsenic emission estimates were developed based on the measurements presented in Table 2-13. EPA testing of the calcine transfer system at ASARCO-Tacoma was performed only when the system was in operation. At the ASARCO-El Paso and Phelps Dodge-Douglas smelters, the systems were tested on a continuous time basis. To compare test results on a similar basis, the ASARCO-Tacoma test results were adjusted from an intermittent to a continuous basis. This was performed by averaging the measured arsenic emission rate obtained from intermittent testing over the total time period of the testing. Also, since the test results at ASARCO-Tacoma represented only half the roasters typically operated at any one time, adjustments were also made to account for the other roasters, in operation, but not tested.

For example, sample run number 1 at ASARCO-Tacoma indicated an arsenic emission rate of 0.46 kg/hr (1.0 lb/hr). Test data⁴⁵ indicated an actual testing time of 15 minutes over an elapsed time period of 1.76 hours. The total arsenic emitted during the 15 minutes was therefore 0.12 kg, which was equivalent to an average emission rate of 0.07 kg/hr (over a time period of 1.76 hours), assuming that the second row of roasters emitted the same amount of fugitive arsenic emissions as the first set of roasters over this same time period. The total uncontrolled fugitive arsenic emission rate during calcine transfer was 0.14 kg/hr.

Corrections were also made to the ASARCO-El Paso and Phelps Dodge-Douglas smelters' test results to account for the collection efficiencies of the calcine transfer systems in use at these smelters. The results thus obtained indicated the average uncontrolled fugitive arsenic emission rates for the ASARCO-Tacoma, ASARCO-El Paso, and Phelps Dodge-Douglas smelters to be 0.16 kg/hr, 0.10 kg/hr, and 0.014 kg/hr, respectively.

For the purpose of developing an emission factor for fugitive arsenic emissions occurring during calcine transfer from multi-hearth roasters, the fugitive arsenic emissions from the three smelters were compared to the quantity of arsenic reporting in the calcine during the test period. The ASARCO-Tacoma, ASARCO-El Paso, and Phelps Dodge-Douglas

test results indicated that an average of 0.05, 0.33, and 2.6 percent, respectively, of the arsenic in the calcine reports in the fugitives. A correction factor for the probable collection efficiencies during calcine transfer at the three smelters is included in the aforementioned results. However, there is some question regarding the accuracy of the arsenic emission estimates made at the Phelps Dodge-Douglas and ASARCO-El Paso smelters. Calcine samples obtained at the Phelps Dodge-Douglas smelter indicated small amounts of arsenic present (less than 0.015 percent). Accurate readings for small arsenic contents are difficult to obtain. Transfer of calcine from roaster to larry cars at the ASARCO-El Paso smelter takes place in a long, rectangular shed. The shed is open at one end and has an exhaust duct at the other end. The configuration of the system is such that not only are fugitive emissions captured by the exhaust system during calcine transfer, but also reentrained fugitive dust generated by the movement of the larry cars and by wind action.

In view of the aforementioned, the ASARCO-Tacoma smelter results were used only to compute the calcine transfer fugitive arsenic emissions factor. The ASARCO-Tacoma test results indicated that an average of 0.005 kg of arsenic reports in the fugitive emissions per kg of arsenic contained in the calcine, or 0.05 percent. This factor was used to estimate calcine transfer of fugitive arsenic emissions from multi-hearth roasters at all domestic copper smelters. The amount of arsenic reporting in the calcine for these estimates was obtained from the process arsenic mass balances provided in Appendix F.

2.3.2.2 Smelting Furnace. As noted previously, three basic types of smelting furnaces are used. These include reverberatory type, electric, and flash furnaces. A discussion on the fugitive emission sources associated with the operation of these furnaces follows.

2.3.2.2.1 Charging. Reverberatory furnaces can be charged by any of the following methods: (1) by dropping the calcine through the arch of the furnace, (2) by using retractable or fixed Wagstaff guns located at the furnace side walls, (3) by charging through ports in the side walls which extend some distance toward the middle of the furnace, and (4) through green charge slingers that cover the entire bath in the smelting zone.

In general, when a green or calcine charge is dropped into the smelting furnace, a rapid increase in gas volume occurs because of metallurgical reactions occurring within the furnace. This can cause a temporary excess pressure in the furnace depending upon the response of the pressure control system. If the pressure exceeds atmospheric level, fugitive emissions can be generated through all the furnace openings. With side-charged reverberatory furnaces, there exists the possibility of a portion of the charge bank flowing, caving in, or sloughing into the molten bath and creating a rapid reaction between the charge and the bath. In such instances, generation of gas can occur so rapidly that the furnace arch can be seriously damaged by the excessive pressure in the furnace.

The seal between the retractable Wagstaff gun and the furnace wall, and the furnace opening required for slinger feed type charging, are additional openings through which fugitive emissions can be emitted when these types of charging techniques are used.

Electric furnaces are charged continuously either from the roof or from the side. The charge almost always consists of dried concentrates or calcine since moisture tends to cause steam explosions. Oxygen requirements for electric furnaces are much smaller compared to reverberatory furnaces because no fuel is being directly burned. There is less likelihood of openings being present to allow excess air as is the case with the reverberatory furnace, thereby minimizing fugitive emissions as a result of pressure surges. When emissions do occur, they generally appear at the seals of the electrodes.

Feed to flash furnaces is usually from a concentrate dryer where the concentrate-to-flux ratio is established by computer, based on the chemical composition of the materials and the desired matte grade. Dried concentrates from the dryer are discharged to the feed receiver by a pneumatic air lift. Air injected into the receiver lifts the dried furnace feed to an air expansion vessel. A drag conveyor from the expansion vessel conveys the feed to the storage bin. The feed from the storage bin to the flash furnace reaction shaft is conveyed by variable speed drag conveyors. A carefully controlled mixture of dry concentrate and pretreated air is then injected to the furnace through concentrate burners from the roof of the reaction shaft. The

charging systems for flash furnaces are gas-tight, and so fugitive emissions are seldom emitted.

Depending upon the method used for charging, and the type of smelting furnace, fugitive emissions can be generated. However, by using add-on control systems which are activated at the time the charge is dropped, effective reduction of potential fugitive emissions can be obtained. Since most smelters are currently using such control systems, it is reasonable to assume that fugitive arsenic emissions during charging of smelting furnaces are negligible.

2.3.2.2.2 Leakage. The structure of most reverberatory furnaces has to allow for thermal expansion. This leaves many leakage points in the reverberatory furnace outer shell. Fugitive emissions from these leakage points are emitted when the pressure in the reverberatory furnace exceeds atmospheric pressure. This, as has been pointed out earlier, can occur during charging and converter slag return.

Proper maintenance is a major factor in minimizing leaks. Hand or spray sealing of all cracks between refractories, if practiced on a routine basis, considerably reduces fugitive emissions due to leakage in a reverberatory furnace.

Usually, reverberatory furnaces are operated under very slight negative pressure at all domestic copper smelters. This is performed not only to prevent fugitive emissions from the multitude of leakage points around the furnace but to avoid overheating of the furnace by providing the cooling effect of air infiltration. Pressure controls are used to maintain a slight negative pressure and also to ensure that pressure surges are kept under control.

In electric furnaces, there is much less of a requirement for providing oxygen to the furnace as compared to the fuel-fired reverberatory furnace. Therefore, these furnaces are usually better sealed. Thus, if a positive pressure is momentarily generated, fugitive emissions due to leakage are considerably less.

The construction of flash furnaces is such that they are virtually gas-tight. This prevents leakage of emissions and cooling by air infiltration.

It is reasonable to assume that fugitive arsenic emissions due to leakage from smelting furnaces are negligible provided they are operated

and maintained properly. Based on this observation, it was concluded that normally no fugitive arsenic emissions are discharged due to leakage.

2.3.2.2.3 Matte tapping. Matte tapping is a principle fugitive emission source at the smelting furnace. Smelting furnaces have from one to three matte tap holes with associated launders on each side. Normally, only one tap is used at a time. The launder directs the flowing matte to a point where it can be collected in a large ladle. Fugitive emissions are observable from the point at which the matte leaves the furnace to the location where it enters the ladle. Typically, a matte tapping operation takes 5 to 15 minutes.

EPA performed testing at the ASARCO-Tacoma,⁴⁶ ASARCO-El Paso,⁴⁷ and Phelps Dodge-Ajo⁴⁸ smelters to determine captured fugitive arsenic emissions during matte tapping. The results are presented in Table 2-14.

Fugitive arsenic emission estimates for matte tapping were developed based on the results of the arsenic emission measurements presented in Table 2-14. It was assumed that complete capture of matte tapping fugitive emissions was obtained by the exhaust hood systems. EPA testing of the matte tapping operations at ASARCO-Tacoma was only performed when actual matte tapping was being conducted. However, the testing at the ASARCO-El Paso and Phelps Dodge-Douglas smelters was performed on a continuous basis over a period of time. To compare the test results on a similar basis, the ASARCO-Tacoma test results were therefore adjusted from an intermittent to a continuous basis. This was performed by averaging the emission rate of arsenic obtained from testing during the time the matte tapping system was in operation over a 24-hour time period. For example, sample run number 1 at ASARCO-Tacoma (refer to Table 2-14) indicated an arsenic emission rate of 1.69 kg/hr (3.73 lb/hr). Process data^{49,50} indicated that 7 minutes are required to fill a matte ladle, and 36 ladles were filled on the day sample run number 1 was made. Therefore, actual time of matte tapping hood system operation was 4.2 hours. Total fugitive arsenic matte tapping emissions emitted were 7.1 kg/hr (15.6 lb/hr). The average fugitive arsenic matte tapping emission rate for sample run number 1 at ASARCO-Tacoma was therefore 0.3 kg/hr (0.65 lb/hr).

Table 2-14. MATTE TAPPING EMISSIONS FROM COPPER SMELTERS

Smelter	Sample Run	Arsenic in Matte lb/hr	Arsenic in Matte (kg/hr)	Arsenic Emissions		Comments
				Concentration g/m	Mass Rate lb/hr	
Phelps Dodge-Ajo	1	2.9	1.3	1.53	0.36	Hood is only on one matte tap hole. The 6 ft. launder was uncovered.
	2	1.1	0.5	1.84	0.51	
	3	3.0	1.4	1.31	0.34	
	Avg.			1.56	0.41	
ASARCO-El Paso	1	44	20	6.65	0.60	Approximately 11×10^3 acfm of additional flow was bypassed.
	2	44	20	6.08	0.58	
	3	N.A.	N.A.	2.81	0.29	
	Avg.			5.18	0.49	
ASARCO-Tacoma	1	108	49	52.42	3.73	The testing was done only during the matte tapping operation.
	2	124	56	243.05	16.60	
	3	104	47	236.18	16.26	
	Avg.			177.22	12.20	

N.A. - Not available

At the ASARCO-El Paso smelter, approximately 11,000 acfm of flow was being bypassed upstream of the test location. The ASARCO-El Paso test results were therefore adjusted by the ratio of the total flow rate (measured flow rate plus bypass flow rate) to the measured flow rate. The results thus obtained, indicated the average fugitive arsenic matte tapping emission rates from the ASARCO-Tacoma, ASARCO-El Paso, and Phelps Dodge-Ajo smelters to be 1 kg/hr (2.15 lb/hr), 0.31 kg/hr (0.67 lb/hr), and 0.19 kg/hr (0.41 lb/hr), respectively.

For the purpose of developing an emission factor for fugitive arsenic matte tapping emissions, the fugitive arsenic emissions from the three smelters were compared to the quantity of arsenic reporting in the matte during the test period. The ASARCO-Tacoma and ASARCO-El Paso test results indicated that an average of 1.9 and 1.5 percent of the arsenic in the matte reports in the fugitives, respectively. The Phelps Dodge-Ajo smelter process samples indicated extremely small amounts of arsenic⁵¹ in the matte (refer to Table 2-14). In view of the difficulty in obtaining accurate readings for such small arsenic contents, the fugitive arsenic matte tapping test results for Phelps Dodge-Ajo were not considered in the development of the emission factor.

Based on the ASARCO-Tacoma and ASARCO-El Paso results, an emission factor of 1.5 percent of the arsenic in the matte was assumed to report in the matte tapping fugitive emissions. This emission factor was then used to estimate fugitive arsenic matte tapping emissions at all the domestic copper smelters regardless of the kind of smelting furnaces in use. The amount of arsenic in the matte at these smelters was obtained from the process arsenic mass balances in Appendix F.

2.3.2.2.4 Slag tapping. Slag tapping is a principle fugitive emission source at the smelting furnace. Slag tap ports and slag launders have been observed to emit less fugitive emissions than those emitted during matte tapping operations. However, fugitive emissions are observable from the point of the slag leaving the furnace to the location where it enters the ladle. Typically, a slag tapping operation takes 10 to 20 minutes.

EPA performed testing at the ASARCO-Tacoma smelter⁵² to estimate fugitive arsenic emissions during slag tapping and to evaluate the

capture system in use at the smelter. At the ASARCO-Tacoma smelter, both the slag tap hole and the slag pot are provided with exhaust hoods, and the slag launder is covered. The captured slag tapping emissions are ducted to the brick flue. The emissions sampling was conducted in the duct leading to the brick flue. Results of this testing are provided in Table 2-15.

Testing at the ASARCO-Tacoma smelter was only performed when slag was being tapped from the reverberatory furnace. Three sample runs were made, and during these runs the slag was also analyzed for arsenic content. The actual test time for sample run number 1 was 60 minutes. On the day sample run number 1 was made, 120 pots of slag were dumped. Approximately 3 minutes were required to fill a slag pot.⁵³ The actual on-time for the slag tapping exhaust hood system was therefore 6 hours. At an emission rate of 0.25 kg/hr (0.56 lb/hr) the arsenic emitted over a 14 hour period was 1.5 kg (3.3 lb) at an average rate of 0.06 kg/hr (0.14 lb/hr). Similar calculations for sample runs 2 and 3 were performed, and an average arsenic emission rate of 0.12 kg/hr (0.25 lb/hr) was obtained for the three sample runs.

For the purpose of developing an emission factor for fugitive arsenic slag tapping emissions, the arsenic reporting in the fugitives was compared to the amount of arsenic in the furnace slag. It was assumed that the arsenic in slag tapping fugitives-to-arsenic in slag ratio remained constant regardless of the type of smelting furnace. Also, fugitive arsenic emissions discharged during slag tapping at the ASARCO-Tacoma smelter were all captured by the exhaust hood system.

At the ASARCO-Tacoma smelter this comparison indicated that an average of about 0.1 percent of the arsenic in the slag (samples taken during test period) reported in the fugitive emissions. Based on these results, a factor of 0.1 percent arsenic in the slag was assumed to report in the slag tapping emissions at all smelters. The amount of arsenic in the slag at each smelter was obtained for the process mass balances discussed in Appendix F.

2.3.2.2.5 Converter slag return. Converter slag is returned to the reverberatory and electric furnaces through the converter slag return launder. This is either a simple channel with an opening in the furnace wall or a mechanically operated chute.

Table 2-15. SLAG TAPPING FUGITIVE ARSENIC EMISSIONS
FROM ASARCO-TACOMA

Sample Run	Arsenic in Slag		Measured Emissions Concentration Mass Rate		Comments
	lb/hr	kg/hr	g/m ³	lb/hr	
1	208	94	7.94	0.56	Testing was only done when the slag was being tapped.
2	275	125	23.04	1.43	
3	290	132	18.16	1.17	
Avg.			16.38	1.05	

The number of times converter slag is returned to the furnace depends upon the number of converters and the operating level of the smelter. Each time the slag is returned, pressure fluctuations occur in the furnace. These fluctuations are due to the agitation in the bath and the rapid chemical reactions with the slag constituents. This tends to generate fugitive emissions through the relatively large converter slag opening.

To develop an emission factor for fugitive arsenic emissions discharged during converter slag return to the smelting furnace, tests were performed by EPA at the ASARCO-Tacoma smelter.⁵⁴ The emissions during converter slag return were sampled during 1 to 3 minute intervals when slag returned to the reverberatory furnace from the converters. Since this procedure occurs only for a short duration, testing was performed for 3 days to obtain an adequate sample for analysis.

The test results over a sample period of 23 minutes (18 ladles of converter slag returns) indicated 0.13 kg/hr (0.3 lb/hr) of arsenic was emitted. The total actual elapsed time during this test period was 5 hours. Therefore, the average fugitive arsenic emission rate during converter slag return was 0.01 kg/hr (0.02 lb/hr). Analysis of the converter slag indicated that during the 3 days in which the tests were performed, an average of 25 kg/hr (56 lb/hr) of arsenic was being returned from the converters to the furnace with the slag. Comparison of the arsenic in the fugitives to the arsenic in the converter slag indicated 0.0004 kg of arsenic reports in the fugitives per 1 kg of arsenic returned with the slag.

Based on these results, it was concluded that the amount of arsenic emitted (0.01 kg/hr) during converter slag return was negligible. It should be noted that the arsenic input at the ASARCO-Tacoma smelter is higher than the combined arsenic input at all the other smelters.

2.3.2.3 Converter.

2.3.2.3.1 Charging. During converter charging, the converter is tilted by a drive mechanism until the mouth of the converter is approximately 45 degrees from the vertical. Fugitive emissions during this operation result when matte or other materials such as reverts flux are poured from a ladle into a converter. The gate on the primary hood is retracted

to its highest position. An overhead crane lifts the matte ladle above the mouth of the converter and pours the matte into the converter by tilting the ladle. During this operation, visible emissions are heavy, but of short duration. When charging is completed, blowing air is turned on while the tuyeres are above the liquid level of the molten bath. The converter is rotated until its mouth is in its topmost position, contained within the primary hood. The gate is then lowered and the blowing cycle commences.

2.3.2.3.2 Blowing. Most domestic smelters have attempted to provide relatively close fitting primary hoods on converter openings. These hoods are used to contain and capture offgases generated during blowing operations. However, these hoods at best do not completely seal the opening since sufficient space has to be provided for easy movement of the converter shell. This is to allow for converter shell irregularities and the molten copper buildup on the shell due to splashing during the blowing operation. Some fugitive emissions are discharged through these openings, especially when pressure surges occur during converter blowing, and rapid adjustments are not made by the duct damper system.

2.3.2.3.3 Skimming. During skimming operations, the mouth of the converter is rotated to a position between 65 to 85 degrees from the vertical, depending upon the bath level. The blowing air remains on as the converter is rolled out, until the tuyeres are above the surface of the bath. This action results in significant quantities of fugitive emissions, but is necessitated by equipment requirements. Slag is skimmed from the converter mouth into a slag ladle. Fugitive emissions are visible during this operation. The primary hood gate may not be fully retracted during skimming; however, the hood is isolated by dampers from the main duct system to keep dilution air from mixing with the high SO_2 offgases from blowing converters. At the completion of skimming, the converter mouth is again rotated to its vertical position within the hood. The gate is fully extended, and the blowing cycle resumes.

2.3.2.3.4 Pouring. As the blister copper is poured, the converter is slowly rotated downward until its mouth reaches a position approximately 90 to 125 degrees from the vertical, depending upon the size of the

pour and the buildup within the converter. The hood gate may be partially extended during this operation. Fugitive emissions during this operation result as the blister copper is poured from the converter into the ladle. After the blister pour, the converter mouth is rotated upward to a position approximately 45 degrees from the vertical to await a new matte charge and the start of a new cycle.

2.3.2.3.5 Holding. There are times during normal smelting operations when material, either slag or blister copper, cannot be immediately transferred from the converters to the ladles. This may be due to such conditions as unavailability of the crane, refining furnace operations not allowing additional feed material, or others. It then becomes necessary for the converter to be placed in a holding mode. In this mode the converter is rotated until the mouth of the converter is 30 to 45 degrees from the vertical to keep the tuyeres out of the bath. This results in fugitive emissions from the molten material in the converter being discharged into the converter building.

2.3.2.3.6 Converter leaks. Since the ends of most Pierce-Smith converters are joined by bolts and springs, they occasionally leak at the end joint. When this leakage is located below the molten material surface, it is usually repaired rapidly to prevent major erosion. However, in those cases where it is located above the charge surface, it may not be repaired. Thus, fugitive emissions may occur at this point.

EPA performed testing at the ASARCO-El Paso smelter⁵⁵ to develop a fugitive arsenic emission factor for fugitive emissions occurring during converting. The results indicated an emission factor of 150 g of arsenic per 1 kg of arsenic contained in the converter primary offgas stream. Thus the emission factor of 15 percent of the arsenic contained in the converter primary offgas, based on test data from ASARCO-El Paso, was used for estimating converter fugitive emissions at the remaining low-arsenic throughput copper smelters.

2.3.2.4 Anode Furnace. Refining of blister copper to anode copper is performed in rotary-type refining furnaces which are similar to Pierce-Smith converters. Unlike converters, however, these furnaces have no control whatsoever. Offgases generated during charging,

blowing, skimming, holding, and pouring are discharged directly to the building atmosphere from the furnace mouth. It should be noted, however, that emissions generated in the anode or refining furnaces are considerably less significant both in terms of volume and arsenic content than from converters. This is because the quantity of impurities removed consists of only about 1 percent of the molten material processed.

Tests by ASARCO-Tacoma were performed separately during the various phases of the anode furnace operations.⁵⁶ The results indicated an anode furnace fugitive emission factor of 110 g of arsenic per 1 kg of arsenic contained in the blister copper. Thus an emission factor of 11 percent of the arsenic contained in the blister copper was obtained, based on test data from ASARCO-Tacoma. This emission factor was then used to estimate fugitive arsenic emissions from anode furnaces at the other domestic smelters.

2.3.2.5 Miscellaneous Fugitive Emission Sources.

2.3.2.5.1 Dust handling and transfer. Dust handling and transfer can generate fugitive emissions if carelessly performed. However, most smelters take reasonable precautions to minimize fugitive emissions from dust handling and transfer. Dust transfer from control devices onto conveyors is typically performed by mechanically timed and activated rotary valves or twin gravity self-closing gates. These conveyors are generally covered by housings and discharge into storage bins from which dust may be withdrawn as desired. Dust transfer from storage bins is usually through dust-tight connections to surface transportation units such as tank trucks and dumpsters. Cleaning and unloading of dust from flues and settling chambers is performed by conveyors which feed into hoppers provided at spaced intervals underneath the flues and settling chambers. Both screw and drag-type conveyors are used. These flue dusts are usually treated in a pugmill or pelletizing disc where moisture is added. The wet dust is then transferred to a bedding area, blended with other feed constituents, and recycled. Dust from waste heat boilers and crossover flues is usually removed by hand methods, water-bomb lances, slugger guns, and other methods. This dust is handled and transported by surface vehicles to the smelter flux crushing system. A more detailed description of dust transfer, handling, and conveying is given in Section 3.1.2.5.

In the transfer, handling, and conveying of dust from control device storage hoppers, smelter flues, and dust chambers, it was assumed that all transfer systems such as screw or drag type conveyors are dust-tight. The uncontrolled fugitive arsenic emissions from these systems were assumed to not exceed 0.1 percent of the arsenic in the dust collected at arsenic drop-out points such as control device storage hoppers, smelter flues, dust chambers, and waste heat boilers. This emission factor was based on particulate (dust) emission rates found in grain transfer, asphalt batching, and other industries involved in transfer, handling, and conveying operations. In these industries, 0.1 percent of the dust transferred, handled, or conveyed is estimated to appear as fugitives.⁵⁷

2.3.2.5.2 Ladles. Normal process fluctuations may require that ladles containing matte, converter slag, or blister copper be temporarily set aside until needed. Because these ladles contain molten material, some emissions can be observed due to fuming. These, however, are short-lived. The exposed surface of the material cools rapidly, forming a solidified layer or skull which greatly limits fugitive emissions. It was therefore assumed that no fugitive arsenic emissions are discharged from ladles once they are filled.

2.3.2.5.3 Slag dumping. Smelting furnace slag is disposed of by water granulation or by transport in the molten state for dumping a short distance from the smelter. Slag dumping is the more widely used method. The slag is transported to the dump site by train or slag hauler. The slag train is usually comprised of a number of slag pots or ladles on flat cars. Solidification at the surface of the slag in the pots is fairly rapid. Fugitive emissions during transportation to the dumping site are therefore limited. However, during dumping of slag at the dumping site, substantial fugitive emissions, although short in duration (less than 1 minute), can be observed.

Testing was performed at the ASARCO-Tacoma smelter by EPA to determine the magnitude of fugitive arsenic emissions during slag dumping.⁵⁸ Reverberatory slag from slag pots was analyzed for arsenic content on exit from the reverberatory furnace and after the slag was deposited on the dump site. Process sample analysis was performed on four separate days. The test results obtained are listed in Table 2-16.

Table 2-16. REVERBERATORY FURNACE SLAG
ANALYSIS FOR ARSENIC CONTENT AT ASARCO-TACOMA

Sample Run	Percent arsenic in slag at exit from furnace slag launder	Percent arsenic in slag at dump site
1	0.33	0.40
2	0.38	0.52
3	0.46	0.44
4	0.49	0.29
Avg.	0.42	0.41

Test results indicated that in the first two of the four samples the arsenic content of the reverberatory furnace slag increased in concentration at the dump site. In the third sample there was a slight decrease in concentration at the dump site. The fourth sample indicated a larger decrease in concentration at the dump site. However, comparison of the averaged results indicated approximately the same concentration of arsenic in the slag at the exit from the furnace and at the dump site. This indicates that fugitive arsenic emissions during slag dumping are negligible.

Table 2-17 presents a summary of the potential fugitive arsenic emission estimates in the absence of control for the 14 low-arsenic throughput primary copper smelters.

TABLE 2-17. SUMMARY OF POTENTIAL FUGITIVE ARSENIC EMISSION ESTIMATES
IN ABSENCE OF CONTROL FOR LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS

Smelter	Emission Source ^a	Arsenic Content		Emission Factor (percent)	Emission Rate, Absence of Control kg/hr
		Present in	Amount, kg/hr		
ASARCO-El Paso	CT	Calcine	146.5	0.05	0.07
	ST	Furnace Slag	54.0	0.1	0.05
	MT	Matte	48.1	1.5	0.7
	CONV	Process Offgas	76.2	15.0	11.4
	AF	Anode Furnace	12.1	11.0	1.3
	FDH	Transferred Dust	260.0	0.1	0.26
ASARCO-Hayden	ST	Furnace Slag	99.0	0.1	0.1
	MT	Matte	97.0	1.5	1.5
	CONV	Process Offgas	45.0	15.0	6.8
	AF	Anode Furnace	20.0	11.0	2.2
	FDH	Transferred dust	194.0	0.1	0.2
Tennessee Chemical Co. - Copperhill	ST	Furnace Slag	0.4	0.1	0.0004
	MT	Matte	0.7	1.5	0.01
	CONV	Process Offgas	0.5	15.0	0.08
	FDH	Transferred Dust	0.6	0.1	0.0006
Inspiration-Miami	ST	Furnace Slag	14.1	0.1	0.01
	MT	Matte	5.4	1.5	0.08
	CONV	Process Offgas	1.5	15.0	0.22
	AF	Anode Furnace	0.7	11.0	0.08
	FDH	Transferred Dust	1.9	0.1	0.002
Kennecott-Garfield	ST	Furnace Slag	33.0	0.1	0.03
	MT	Matte	15.7	1.5	0.2
	CONV	Process Offgas	6.0	15.0	0.9
	AF	Anode Furnace	13.1	11.0	1.5
	FDH	Transferred Dust	189.5	0.1	0.2
Kennecott-Hayden	ST	Furnace Slag	2.2	0.1	0.002
	MT	Matte	7.2	1.5	0.11
	CONV	Process Offgas	5.0	15.0	0.8
	AF	Anode Furnace	0.09	11.0	0.01
	FDH	Transferred Dust	4.1	0.1	0.004
Kennecott-Hurley	ST	Furnace Slag	0.8	0.1	0.001
	MT	Matte	0.8	1.5	0.014
	CONV	Process Offgas	0.4	15.0	0.054
	AF	Anode Furnace	0.16	11.0	0.02
	FDH	Transferred Dust	1.6	0.1	0.002

TABLE 2-17. SUMMARY OF POTENTIAL FUGITIVE ARSENIC EMISSION ESTIMATES
IN ABSENCE OF CONTROL FOR LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS (Concluded)

Smelter	Emission Source ^a	Arsenic Content		Emission Factor (percent)	Emission Rate, Absence of Control kg/hr
		Present in	Amount, kg/hr		
Kennecott-McGill	ST	Furnace Slag	19.4	0.1	0.02
	MT	Matte	34.0	1.5	0.5
	CONV	Process Offgas	35.6	15.0	5.3
	AF	Anode Furnace	3.3	11.0	0.4
	FDH	Transferred Dust	14.9	0.1	0.02
Magma-San Manuel	ST	Furnace Slag	0.4	0.1	0.0004
	MT	Matte	0.6	1.5	0.01
	CONV	Process Offgas	0.4	15.0	0.06
	AF	Anode Furnace	0.06	11.0	0.006
	FDH	Transferred Dust	0.7	0.1	0.0007
Phelps Dodge-Ajo	ST	Furnace Slag	10.1	0.1	0.01
	MT	Matte	4.1	1.5	0.06
	CONV	Process Offgas	2.3	15.0	0.3
	AF	Anode Furnace	0.9	11.0	0.1
	FDH	Transferred Dust	11.8	0.1	0.01
Phelps Dodge-Douglas	CT	Calcine	10.6	0.05	0.005
	ST	Furnace Slag	6.2	0.1	0.006
	MT	Matte	4.2	1.5	0.06
	CONV	Process Offgas	3.2	15.0	0.5
	AF	Anode Furnace	0.2	11.0	0.02
Phelps Dodge-Hidalgo	FDH	Transferred Dust	1.9	0.1	0.002
	ST	Furnace Slag	3.0	0.1	0.003
	MT	Matte	1.3	1.5	0.02
	CONV	Process Offgas	0.9	15.0	0.14
	AF	Anode Furnace	0.6	11.0	0.07
Phelps Dodge-Morenci	FDH	Transferred Dust	4.4	0.1	0.004
	ST	Furnace Slag	3.8	0.1	0.004
	MT	Matte	6.7	1.5	0.1
	CONV	Process Offgas	5.3	15.0	0.8
	AF	Anode Furnace	0.5	11.0	0.06
Copper Range - White Pine	FDH	Transferred Dust	9.6	0.1	0.009
	ST	Furnace Slag	0.2	0.1	0.0002
	MT	Matte	0.4	1.5	0.006
	CONV	Process Offgas	0.2	15.0	0.04
	AF	Anode Furnace	0.2	11.0	0.02
Copper Range - White Pine	FDH	Transferred Dust	0.4	0.1	0.0004

^aSources: CT - Calcine Transfer MT - Matte Tapping AF - Anode Furnace
ST - Slag Tapping CONV - Converter Operations FDH - Flue Dust Handling, Transfer, and Conveying

2.4 REFERENCES

1. Background Information Document for Review of New Source Performance Standards for Primary Copper Smelters (Draft). U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. EPA Contract No. 68-02-3056. October 1982. p. 3-2.
2. Telecon. Whaley, G., Pacific Environmental Services, with Buttermann, W., U.S. Bureau of Mines. Primary copper smelter production in 1982. March 2, 1983.
3. Reference 1, p. 3-3.
4. Field Surveillance and Enforcement Guide for Primary Metallurgical Industries. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. Publication No. EPA 450/3-73-002. December 1973. p. 175.
5. Reference 4, p. 180.
6. Letter and attachments from J.W. Maksym, White Pine Copper Division, Copper Range Company, to J.R. Farmer, U.S. Environmental Protection Agency. March 17, 1983. Response to Section 114 Information Request.
7. Letter and attachments from L.R. Judd, Phelps Dodge Corporation to J.R. Farmer, U.S. Environmental Protection Agency. April 7, 1983. Response to Section 114 Information Request.
8. Letter and attachment from R.A. Malone, Kennecott Minerals Company to J.R. Farmer, U.S. Environmental Protection Agency, March 16, 1983. Response to Section 114 Information Request.
9. Letter and attachments from M.O. Varner, ASARCO, Inc. to J.R. Farmer, U.S. Environmental Protection Agency, March 16, 1983. Response to Section 114 Information Request.
10. Letter and attachment from J.W. George, Tennessee Chemical Company, to J.R. Farmer, U.S. Environmental Protection Agency, April 6, 1983. Response to Section 114 Information Request.
11. Letter and attachment from J.H. Boyd, Magma Copper Company, to J.R. Farmer, U.S. Environmental Protection Agency, March 15, 1983. Response to Section 114 Information Request.
12. Letter and attachment from T.B. Larsen, Inspiration Consolidated Copper Company, to J.R. Farmer, U.S. Environmental Protection Agency. March 14, 1983. Response to Section 114 Information Request.
13. Process Parameters for Primary Copper Smelters and Their Effects on Arsenic Emissions (Draft). U.S. Environmental Protection

Agency. Research Triangle Park, North Carolina. EPA Contract No. 68-02-2606. June 1978.

14. Reference 1, p. 3-11, 3-12.
15. Reference 1, p. 3-18.
16. Telecon. Whaley, G., Pacific Environmental Services, with Larsen, T., Inspiration Consolidated Copper Company. Status of Hoboken converters. March 4, 1983.
17. Reference 1, p. 3-36.
18. Mackey, P.J., et al. Minor Elements in the Noranda Process. (Presented at the 104th Annual AIME Meeting. New York. February 16-20, 1975.)
19. Newton, J. and C.L. Wilson. Metallurgy of Copper. London. John Wiley and Sons, Inc. 1942.
20. Correspondence from Mr. Jim Henderson, ASARCO, Incorporated, to Mr. D.R. Goodwin, Environmental Protection Agency, August 30, 1973.
21. Yazawa, A. Thermodynamic Considerations of Copper Smelting. Canadian Metallurgical Quarterly. 13(3):443. 1974.
22. Yazawa, A., and T. Azakami. Thermodynamics of Removing Impurities During Copper Smelting. Canadian Metallurgical Quarterly. 8:257. 1969.
23. Correspondence from K.W. Nelson, ASARCO, Incorporated, to J. Padgett, Environmental Protection Agency. March 17, 1976.
24. Harris, D.L. Air Pollution Emission Test - Particulate and Arsenic Emission Measurements from a Copper Smelter. Volume I (text). Monsanto Research Corporation. EMB Report No. 77-CUS-6. June 20-30, 1977.
25. Schwitzgebel, K., et al. Trace Element Study at a Primary Copper Smelter. Prepublication copy. U.S. Environmental Protection Agency. Contract No. 68-01-4136. January 1978.
26. Burton, D.J. The Proposed Arsenic Standard: Feasibility and Estimated Costs of Compliance for Three U.S. Copper Smelters. Occupational Safety and Health Administration. Washington, D.C. Contract B-9-F-5-1663. March 25, 1975.
27. Correspondence from Pickering, I.G., Vice President Environmental Affairs, Kennecott Copper Corporation, to D.R. Goodwin, Director, ESED, Environmental Protection Agency. May 9, 1978. Data for Kennecott-Hayden.

28. Stankovic, D. Air Pollution Caused by Copper Metallurgy Assemblies in Bor. Institute for Copper. Bor. Environmental Protection Agency. No. 02-513-1.
29. Conversation with Mr. Hank Hansen, Environmental Engineer, Kennecott Copper Corporation, Salt Lake City, September 26, 1978.
30. Ruddle, R.W. The Physical Chemistry of Copper-Smelting. Institute of Mining and Metallurgy. London. 1953.
31. Turnbull, D.L., "Converter Practice at Mufulira," Seventh Commonwealth Mining and Metallurgical Congress, 1961.
32. Rozlovskii, A.A., "Behavior of Arsenic in the Production of Nonferrous Metals," Tsvetnye Metally/Nonferrous Metals, Number UDC 669.778.
33. Paulson, D.L., et al. Smelting of Arseniferous Copper Concentrate in an Electric Arc Furnace. U.S. Bureau of Mines. Report of Investigation No. 8144. 1976.
34. Reference 18.
35. Reference 18.
36. Reference 23.
37. Reference 24.
38. Schwitzgebel, K., et al. Trace Element Study at a Primary Copper Smelter. Prepublication copy. U.S. Environmental Protection Agency. Contract No. 68-01-4136. January 1978.
39. Harris, D.L. Air Pollution Emission Test - Particulate and Arsenic Emission Measurements from a Copper Smelter. Volume I (text). Monsanto Research Corporation. EMB Report No. 77-CUS-6. June 20-30, 1977.
40. EPA testing at Anaconda (process emissions).
41. EPA testing at Kennecott-Hayden (process emissions).
42. TRW Environmental Engineering Division, Emission Testing of ASARCO Copper Smelter, Tacoma, Washington. EMB Report No. 78-CUS-12.
43. TRW Environmental Engineering Division. Emission Testing of ASARCO Copper Smelter, El Paso, Texas. EMB Report No. 78-CUS-7. April 25, 1978.
44. TRW Environmental Engineering Division. Emission Testing of Phelps Dodge Copper Smelter, Douglas, Arizona. EMB Report No. 78-CUS-8. February 1979.

45. Reference 42.
46. Reference 42.
47. Reference 43.
48. TRW Environmental Engineering Division. Emission Testing at Phelps Dodge Copper Smelter, Ajo Smelter. EMB Report No. 78-CUS-9. February 1979.
49. Correspondence from Mr. K.W. Nelson, ASARCO, Incorporated, to Mr. Don R. Goodwin, Environmental Protection Agency, September 14, 1978.
50. Correspondence from Mr. A.L. Labbe, ASARCO, Incorporated, regarding process data for the ASARCO-Tacoma plant for the arsenic sampling period September 12-24, 1978, to Mr. S.T. Cuffe, Environmental Protection Agency. November 20, 1978.
51. Reference 48.
52. Reference 42.
53. Reference 50.
54. Reference 42.
55. Reference 43.
56. Godsey, E.S. Tacoma Plant Anode Furnace Emissions. ASARCO Salt Lake City office. August 8, 1975.
57. Newton, J. and C.L. Wilson. Metallurgy of Copper. London. John Wiley and Sons, Inc. 1942.
58. Reference 42.

3.0 CONTROL TECHNOLOGY

This chapter identifies alternative control techniques which can be applied to process and fugitive emission sources at primary copper smelters to control arsenic emissions. The amount of arsenic emission reduction which can be achieved by the application of these control techniques as well as major factors affecting their performance are discussed.

3.1 ALTERNATIVE CONTROL TECHNIQUES

3.1.1 Process Emission Controls

3.1.1.1 General Considerations. As discussed in Section 2.0, much of the arsenic entering the copper smelting process is volatilized and eliminated as metallic oxide in the process offgas streams. This is a result of the very high temperatures associated with the pyrometallurgical processes used and the inherent volatility of arsenic and its prevalent oxide, arsenic trioxide (As_2O_3). The extreme volatility of arsenic, and especially arsenic trioxide, is the single most important factor affecting the controllability of arsenic emissions from sources at primary copper smelters.

Several studies have been made to determine the vapor pressure of arsenic trioxide in air at various temperatures.¹ Table 3-1 presents vapor pressure data for arsenolite (As_4O_6), the more common form of arsenic trioxide and the most abundant arsenic compound in smelter offgases.^{2,3} Also presented are the arsenic concentrations at saturation corresponding to the temperatures and vapor pressures listed. Figure 3-1 illustrates graphically the vapor pressure-temperature relationship indicated by these data. This figure illustrates a significant logarithmic increase in the vapor pressure of arsenic trioxide, and thus the amount of arsenic which can exist in the vapor state, with temperature.

Table 3-1. SUMMARY OF As_4O_6 VAPOR PRESSURE DATA AND CORRESPONDING ARSENIC CONCENTRATION AT VARIOUS TEMPERATURES

Temperature, °C(°F)	Vapor pressure, mm Hg	Arsenic concentration, g/m ³
457.2 (855.0)	760	5.0×10^3
412.2 (774.0)	400	2.81×10^3
332.5 (630.5)	100	7.94×10^2
299.2 (570.6)	40	3.36×10^2
259.7 (499.5)	10	90.20
212.5 (414.5)	1.0	9.90
200.0 (392.0)	0.910	9.25
175.0 (347.0)	0.175	1.88
150.0 (302.0)	2.77×10^{-2}	0.315
125.0 (257.0)	3.58×10^{-3}	0.043
110.0 (230.0)	8.81×10^{-4}	0.011
100.0 (212.0)	3.31×10^{-4}	0.0043
90.0 (194.0)	1.18×10^{-4}	0.0016

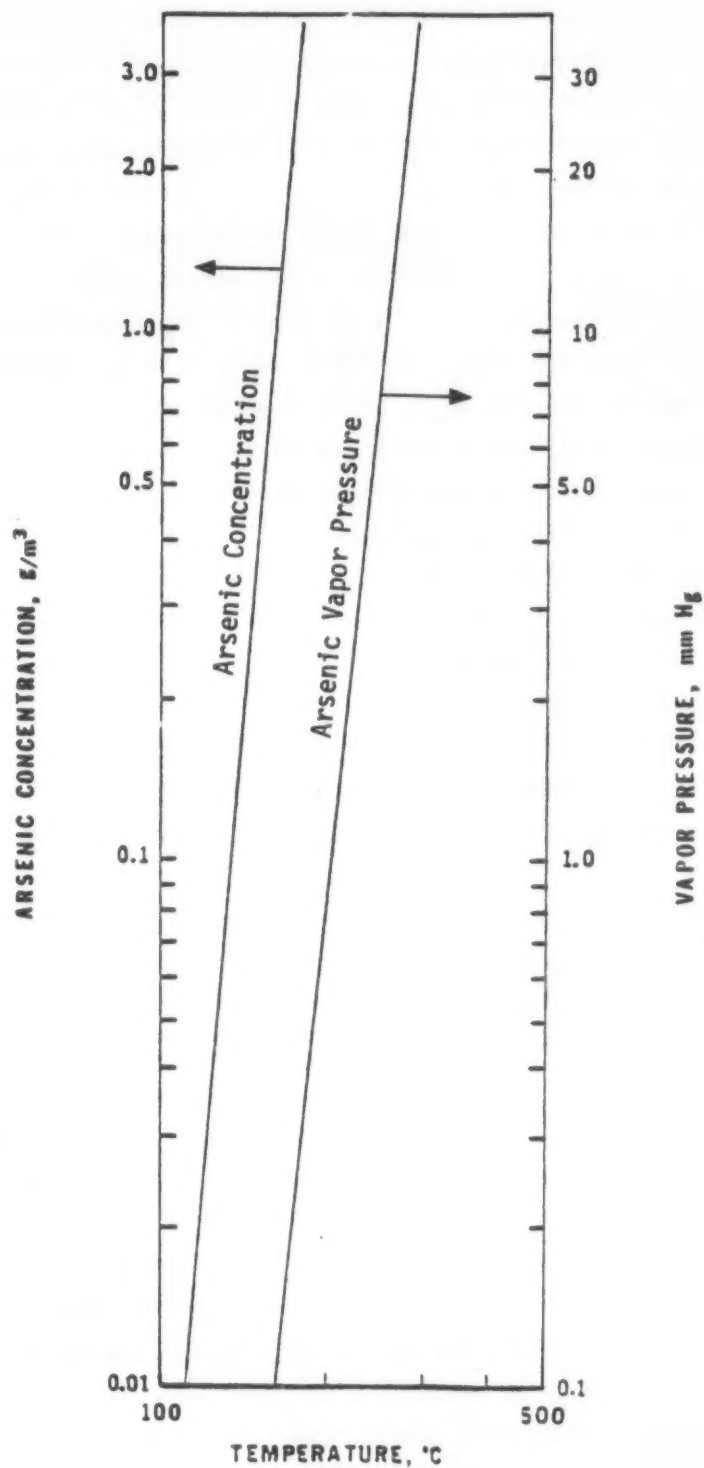


Figure 3-1. Arsenic Trioxide Vapor Pressure and Saturated Vapor Concentration with Temperature

Furthermore, the vapor pressure data indicate that arsenic trioxide maintains an appreciable vapor pressure at relatively low temperatures.

For example, Table 3-1 shows that at 200°C (392°F), which is typical of the outlet temperature of many of the control devices currently used in the industry, 9.25 grams of arsenic trioxide per m³ of gas (g/m³) (4.04 gr/ft³) could exist in the vapor form. Even at a temperature as low as 125°C (257°F), a gas stream could contain 0.043 g/m³ (0.019 gr/ft³) of arsenic trioxide as vapor. Any concentration higher than 9.25 g/m³ in a gas stream at 200°C would lead to condensation of some of the vapor, and the As₄O₆ would then exist in two phases: a vapor or gaseous phase and a condensed or particulate phase. The vapor would pass through a particulate control device without collection, while the condensed material would be collected at about the same efficiency as total particulate matter. The implication of these facts with regard to the controllability of arsenic is important. The temperature of the gas stream determines the amount of arsenic trioxide which can exist as vapor and, consequently, the quantity of condensed or particulate arsenic which can potentially be collected in a particulate control device. A lower temperature gas stream is more likely to contain more arsenic trioxide in a form which can be collected in such a device.

An example will serve to illustrate these points. A 2,834 m³/min (100,000 acfm) gas stream at 150°C (302°F) with an arsenic trioxide mass flow rate of 40 kg/hr would have an arsenic concentration of 0.235 g/m³ (0.103 gr/ft³). Table 3-1 shows that at 150°C, the saturation concentration for As₄O₆ is 0.315 g/m³. Therefore, the stream is at a subsaturation level and no condensation, and hence no particulate collection, is predicted. If this stream were cooled to 125°C in a spray chamber, the arsenic concentration at the new flow rate of 2,667 m³/min (94,100 acfm) would increase to 0.250 g/m³ (0.109 gr/ft³). Since the arsenic saturation concentration shown in Table 3-1 for this temperature is 0.043 g/m³, the amount of arsenic leaving the spray chamber in condensed form would be 0.207 g/m³ (33.12 kg/hr), and the remaining amount, 0.043 g/m³, would remain in vapor form. If this stream was then sent to a baghouse collector with a control efficiency for total particulate matter of 96 percent, a total of 0.96 x

33.12 kg/hr = 31.80 kg/hr would be collected. The overall control efficiency for arsenic at the lowered temperature would thus be $31.80/40 = 80$ percent. From Table 3-1 it can be seen that as the temperature is further lowered below 125°C, the saturation concentration becomes very small. In this case, virtually all of the arsenic trioxide present in the stream would condense into a collectible form and the collection efficiency for arsenic would approach the particulate efficiency of 96 percent.

Tests conducted by EPA across a hot electrostatic precipitator (ESP) which controlled particulate emissions from a "green" charge reverberatory smelting furnace further demonstrate this phenomenon.⁴ The electrostatic precipitator was operated at 315°C (600°F) or higher. Measurements for particulate matter conducted using in-stack filters, at the operating temperature of the ESP, demonstrated an overall collection efficiency for particulate matter of about 97 percent. In contrast, arsenic measurements conducted using a modified EPA Method 5 sampling train operated at 121°C (250°F) indicated an average arsenic collection efficiency for the ESP of less than 30 percent (see Table 3-2). Calculations based on the arsenic concentration measured at the hot ESP inlet and the saturation concentration data presented in Table 3-1 indicate that the application of a 97 percent effective ESP to the same reverberatory furnace process gas stream which had been cooled to 110°C (230°F) could result in an overall arsenic collection efficiency of 90 percent. These measurements and calculations suggest that, while the subject ESP was reasonably effective in removing material which existed as particulate matter at its operating temperature, any material such as arsenic trioxide which would be predicted to exist in the vapor state at the elevated temperature at which the ESP was operated passed through the ESP with little removal. This demonstrates the need to cool the gas stream to be treated to the extent practicable to condense as much of the arsenic trioxide vapor as possible prior to its entering a control device for collection.

As a result, the alternative control techniques for arsenic process sources considered herein include precooling as an integral part of the overall control system. These include the application of baghouses, high voltage electrostatic precipitators, or high energy

Table 3-2. ARSENIC DATA FOR HOT ESP

Sample run	Inlet				Outlet		Efficiency, percent
	Temp., °C (°F)	Emissions		Temp., °C (°F)	Emissions		
		g/Nm ³ (gr/scf)	kg/hr (lb/hr)		g/Nm ³ (gr/scf)	kg/hr (lb/hr)	
1	328 (622)	0.268 (0.117)	26.8 (59.1)	313 (595)	0.211 (0.092)	24.3 (53.6)	9.3
2	317 (602)	0.325 (0.142)	33.0 (72.7)	321 (610)	0.181 (0.079)	20.2 (44.6)	38.6
3	336 (639)	0.334 (0.146)	34.1 (75.2)	304 (580)	0.199 (0.087)	23.2 (51.1)	32.0
Avg.	327 (621)	0.309 (0.135)	31.3 (69.0)	313 (595)	0.197 (0.086)	22.6 (49.8)	27.8

venturi scrubbers, preceded by gas stream cooling. In addition, these include contact sulfuric acid plants, with their extensive gas precleaning and conditioning systems, applied to process sources which generate offgases containing high concentrations of SO_2 (greater than 3.5 percent).

Before proceeding with the discussions on control techniques, it should be noted that the 30 percent arsenic collection efficiency recorded for the hot ESP cannot be predicted using the vapor pressure data for arsenic trioxide. In fact, given the operating temperature of the ESP (315°C), no arsenic recovery would be predicted because the arsenic concentration in the gas stream was several orders of magnitude lower than that needed to achieve saturation. This suggests (1) that other arsenic compounds less volatile than arsenic trioxide may be present in the gas stream, and/or (2) that condensation, although the principal mechanism in situations where more arsenic trioxide is present than is needed to saturate the gas stream, is not the only mechanism by which arsenic trioxide can be collected.

3.1.1.2 Gas Cooling. Methods commonly applied in the nonferrous metals industries for cooling hot gas streams include radiative cooling, evaporative cooling, and cooling by dilution with ambient air. The dilution method consists of introducing sufficient quantities of ambient air into the hot gas stream so that the resultant gas mixture is at the desired temperature. The ambient air required may be introduced by infiltration or forced draft. Evaporative cooling uses water to cool hot gases in spray or quench chambers. Water is injected into the hot gas stream where the heat contained in the gases vaporizes the injected water, resulting in a temperature reduction. Radiative cooling relies on heat loss due to natural convection and radiation to effect cooling. These losses occur whenever a temperature gradient exists between gases inside a duct and the surrounding air. Cooling of gases by this method requires only that a sufficient heat transfer area be available to obtain the desired cooling. All three methods have advantages and disadvantages.

Although cooling with dilution air is the simplest alternative, its application for the gas volumes and temperatures under consideration may not be economical. Depending on the temperature of the gas stream

to be treated, the amount of dilution air needed to effect cooling could result in a two- to four-fold increase in the total gas volume to be treated, with a corresponding increase in the size and cost of the draft fan and the control device required.

Due to the need for sufficient heat transfer area, radiative cooling requires considerable space. Depending on the temperature of the gas stream to be cooled, the heat transfer areas required could exceed $1.6 \text{ m}^2/\text{m}^3$ ($500 \text{ ft}^2/1000 \text{ ft}^3$) of gas treated. Normally used in the lead industry on zinc fuming operations, radiative cooling devices consist of a series of 10 to 20 U-shaped tubes, each about 3 m (10 ft) in diameter and 20 m (66 ft) in height. In addition, fan horsepower requirements increase due to the increased resistance to gas flow resulting from the added ductwork. The major drawback to radiative cooling, however, is its limited flexibility for temperature control.

Cooling hot gases by evaporative cooling is relatively simple and requires little space. Water spray chambers are currently used at a number of copper smelters for cooling process gases from a variety of sources prior to entering electrostatic precipitators or baghouses for particulate removal. Typically, the spray chambers have a cross-sectional area of about 35 m^2 (375 ft^2) and are 30 to 60 m (100 to 200 ft) in length. The large cross-sectional area results in a low flow velocity and a relatively long residence time. Water is introduced through a series of sprays along the cross section of the chamber. Water requirements vary depending on the temperature of the stream to be cooled and the desired end temperature.

The major difficulty in applying water spray chambers for cooling smelter offgases is the potential for corrosion. The amount of cooling achievable is limited by the dew point of the treated gas stream. As the gases are cooled, water and sulfuric acid mist contained in the gas stream may condense, creating a corrosion problem in the flue system, control device, and stack. While the problem of corrosion attack is potentially severe, it can be negated by the use of appropriate construction materials. Acid resistant cement, stainless steel, nickel, and chromium alloys have been used in several cases. No significant corrosion problems have been reported at primary copper

and lead smelters where spray chambers are used for cooling prior to electrostatic precipitators and baghouses used for particulate matter control.

3.1.1.3 Baghouses (Fabric Filters). Baghouse particulate collectors have historically achieved collection efficiencies in excess of 99 percent, over a broad range of applications. Although extensively used in the primary lead and zinc industries for the collection of particulate and metallurgical fume, their application at primary copper smelters has been limited. ASARCO-Tacoma is the only smelter which currently uses a baghouse for the control of particulate matter contained in smelter offgases.

In principle, particles contained in the treated gas stream are initially captured and retained on the fibers of the fabric by a number of mechanisms, including direct interception, inertial impaction, diffusion, gravitational settling, and electrostatic attraction. Once a mat or cake of dust is formed on the fabric, further collection is achieved by simple sieving. Periodically, the fabric is cleaned by mechanical or other means to allow for disposal of the collected particulate and to maintain the pressure drop across the filter within practical operating limits.

The filtration area required at a specified pressure drop is dependent on the gas volume treated, particulate loading, permeability of the fabric used, resistance properties of the particulate deposited, and the cleaning mechanism used. The pressure drop commonly found in baghouses applied in the nonferrous metals industries ranges from 0.5 to 2.0 kPa (2 to 8 inches H_2O).⁵ The filtering velocity, or air-to-cloth ratio, generally ranges from 0.30 to 0.61 m^3/min per m^2 (1 to 2 acfm/ft²) for conventional mechanical shaker cleaning type baghouses when applied to metallurgical fume. Pulse jet cleaning type units generally operate at higher air-to-cloth ratios, ranging from 1.8 to 3.0 m^3/min per m^2 (6 to 10 acfm/ft²).⁵

Although there is a variety of woven and felted fabrics available, woven Orlon and Dacron bags should be suitable in smelter applications. Both exhibit good resistance to acid attack and may be operated at temperatures ranging up to 135°C (275°F) with no significant deterioration.⁵

Bag life, which varies considerably with operating conditions, should be approximately 1 to 3 years. Closed pressure or closed suction baghouse designs may be used in the applications considered. The baghouse design selected depends on the acid dew point and the consequent corrosion potential of the smelter offgases being treated.

3.1.1.4 Electrostatic Precipitators (ESP's). Single-stage electrostatic precipitators are widely used in the primary copper industry for the control of particulate emissions from smelting facilities. Electrostatic precipitators use electrical forces for the removal of suspended particulates in a gas stream. The process encompasses three basic functions: the charging of particles, the collection of charged particles, and the removal of the collected particles. Particles suspended in the gas stream are charged while passing through a high voltage, direct current corona established between a discharge electrode, usually a small diameter wire which is maintained at high voltage, and a grounded collecting surface (collecting electrode). As the particles pass through the corona, they are bombarded by negative ions emanating from the discharge electrode, and charged within a fraction of a second. The charged particles, influenced by electric field forces, migrate toward the grounded collecting surface where they are deposited and held by electrical, mechanical, and molecular forces. Particulate matter adhering to the collecting surface is periodically dislodged by mechanical rappers or by flushing with water. The material is collected in a hopper and periodically removed for disposal or recycle.

Two principal types of precipitator design are available, the wire-and-plate and wire-in-tube types. In the more common plate-type precipitators, the collecting surface consists of parallel vertical plates spaced 15 to 30 cm apart with wire or rod discharge electrodes suspended vertically between the plates. The plates are typically 4 to 12 m in height and 4 to 7 m in length.⁶ Plate-type ESP's are generally applied directly to process sources for the control of dry particulate matter at elevated temperatures, usually 200 to 340°C (400 to 650°F). The collecting surface in tube-type precipitators consists of a cylinder with the discharge electrode centered along its longitudinal axis. This type of ESP is used exclusively for acid mist elimination

and fine particulate removal prior to acid manufacturing. With either type, a complete precipitator installation consists of several individual subunits positioned both in series and in parallel to achieve the desired collection efficiency.

There are several important factors to be considered in the design and sizing of a precipitator to obtain a desired efficiency. These include the volume, temperature, and moisture content of the gas stream to be treated, and the resistivity, size distribution, and loading of the particulate to be collected. Of these, resistivity is the most important. Resistivity (the reciprocal of conductivity) is dependent on the chemical and physical properties of the particulate, and the temperature of the stream. Because of the presence of metal oxides, the resistivity of smelter dusts is relatively high at reduced temperatures (90 to 200°C) in the absence of natural conditioning agents such as moisture and SO_3 . Too high a resistivity (greater than 10^{10} ohm-cm) may result in excessive sparking, which can seriously limit precipitator performance. Preconditioning with moisture and sulfuric acid has been applied to decrease particle resistivity prior to precipitation.⁷

3.1.1.5 Venturi Scrubbers. In a venturi scrubber, flue gases are passed through a venturi at high velocity, and the scrubbing liquid is introduced at the venturi throat under low static pressure where it is atomized and accelerated by the gas stream. Particles suspended in the gas stream are removed by impaction with the atomized liquid droplets. The wetted particles and entrained liquid are removed by a cyclone or other type of entrainment separator. The collection efficiency achieved, which can be in excess of 99 percent, is directly related to the total amount of energy expended in forcing the gases through the venturi and in atomizing and accelerating the scrubbing liquid. The expended energy is reflected in the pressure drop across the device, which may range from 2.5 kPa (10 in. H_2O) to over 20 kPa (80 in. H_2O). Typical throat velocities for venturi units range from 75 to 100 m/s (15,000 to 20,000 fpm) and liquid-to-gas ratios range from 0.4 to 2 liters/min per m^3/min (3 to 15 gpm/ 10^3 acfm).⁸ It is

important that the liquid-to-gas ratio be sufficiently high to guarantee complete wetting across the venturi cross-section.

The application of venturi scrubbers at primary copper smelters is limited to a few smelters where they are used to augment gas stream precleaning systems and to provide additional gas cooling prior to acid manufacturing.

3.1.1.6 Sulfuric Acid Plants. As noted previously, smelter offgases containing high concentrations of SO_2 (over 3.5 percent) are generally treated in single- or double-contact sulfuric acid plants for SO_2 removal. The presence of solid and gaseous contaminants, such as acid mist, entrained dust, and metal fumes in the treated smelter offgases can present serious difficulties in the operation of an acid plant. The major difficulties caused by these contaminants include the corrosion of heat exchanger tubes, plugging of catalytic beds, deactivation of the catalyst, and contamination of the product acid. As a result, rather extensive measures have to be taken to remove contaminants to ensure that their concentrations are reduced to tolerable levels prior to entering the acid plant.

Table 3-3 contains estimates of the maximum levels of impurities that can be tolerated in smelter offgases used for sulfuric acid manufacturing. The degree of catalyst deterioration experienced at these various impurity levels can be tolerated by shutting down the acid plant once per year to screen the catalyst and repair the equipment. Table 3-3 also contains the estimated upper level of impurities that can be removed by typical gas precleaning systems with prior removal of coarse dust. Although complete removal of contaminants, such as arsenic, from the offgases is not practical, over 99 percent removal is considered achievable.¹⁰

Both hot and cold gas cleaning devices are used. Generally, the offgases are initially treated in a hot electrostatic precipitator where the coarse particulate, which contains large amounts of metals, is removed. The gases exiting the precipitator are then scrubbed in one or more packed-bed or impingement-type scrubbers where, in addition to undergoing further particulate removal, the gases are humidified and cooled. The cooled gases then enter a series of electrostatic

Table 3-3. ESTIMATED APPROXIMATE MAXIMUM IMPURITY LIMITS FOR METALLURGICAL OFFGASES USED^g TO MANUFACTURE SULFURIC ACID^g

Substance	Impurity limits at inlet to acid plant, (mg/Nm ³) ^a	Impurity limits at inlet to gas purification system, (mg/Nm ³) ^{a,b}
Chlorides, as Cl	1.2	125 ^c
Fluorides, as F	0.25	25 ^d
Arsenic, as As ₂ O ₃	1.2 ^e	200
Lead, as Pb	1.2	200
Mercury, as Hg	0.25	2.5 ^f
Selenium, as Se	50 ^e	100
Total solids	1.2	1,000 ^g
H ₂ SO ₄ mist, as 100% acid	50	
Water		400 x 10 ³

^aBasis: dry offgas stream containing 7 percent sulfur dioxide.

^bFor a typical gas purification system with prior coarse dust removal.

^cMust be reduced to 6 mg/Nm³ if stainless steel is used.

^dCan be increased to 500 mg/Nm³ if silica products in scrubbing towers are replaced by carbon; must be reduced if stainless steel is used.

^eCan be objectionable in product acid.

^fCan be increased to 5 to 12 mg/Nm³ if lead ducts and precipitator bottoms are not used.

^gCan be increased to 5,000 to 10,000 mg/Nm³ if weak acid settling tanks are used.

mist precipitators where acid mist, fine particulates, and volatile metals are removed prior to entering the acid plant. If more elaborate cleaning is required, venturi-type scrubbers are used upstream of the cooling towers.

The basic steps in the contact process for the manufacture of sulfuric acid from sulfur dioxide-bearing gases are shown in Figure 3-2. As noted, the offgases are cooled and cleaned to remove particulates and volatile metals. Acid mist is removed in an electrostatic mist precipitator, and the gases are dried with 93 percent sulfuric acid. The dry gases then pass through a series of gas-to-gas heat exchangers to heat the offgases to the optimum temperatures for the catalytic conversion of sulfur dioxide (SO_2) to sulfur trioxide (SO_3). Single-contact acid plants use three or four stages of catalytic converters, whereas dual-contact plants use one, two, or three stages of catalyst before the first absorption tower. Since the conversion of sulfur dioxide to sulfur trioxide is exothermic, the converter outlet gases must be cooled before passing through the absorption tower. These outlet gases are passed countercurrent to the inlet gases in the heat exchangers mentioned above. The sulfur trioxide is then absorbed by 98 percent sulfuric acid in an absorption tower to yield the product. In a single-contact acid plant, the remaining gases are then treated to remove acid mist and spray, and then vented to the atmosphere.

In a dual-contact acid plant, the gases exhausted by the first absorption tower are passed through a second series of heat exchangers and catalytic converter stages to oxidize the sulfur dioxide remaining in the gases. Normally, this step employs one or two stages of catalyst. The gases then pass through a second absorption tower, where sulfur trioxide is absorbed by sulfuric acid as in the first absorption tower. The waste gases are then treated to remove acid mist and spray, and vented to the atmosphere.

3.1.1.7 Factors Affecting Performance. The alternative arsenic emission control techniques considered above share a common element. They all consist of cooling the gas stream to condense arsenic (provided a sufficient quantity of arsenic is present in the gas stream) and collecting the resultant fume in a high efficiency collection device.

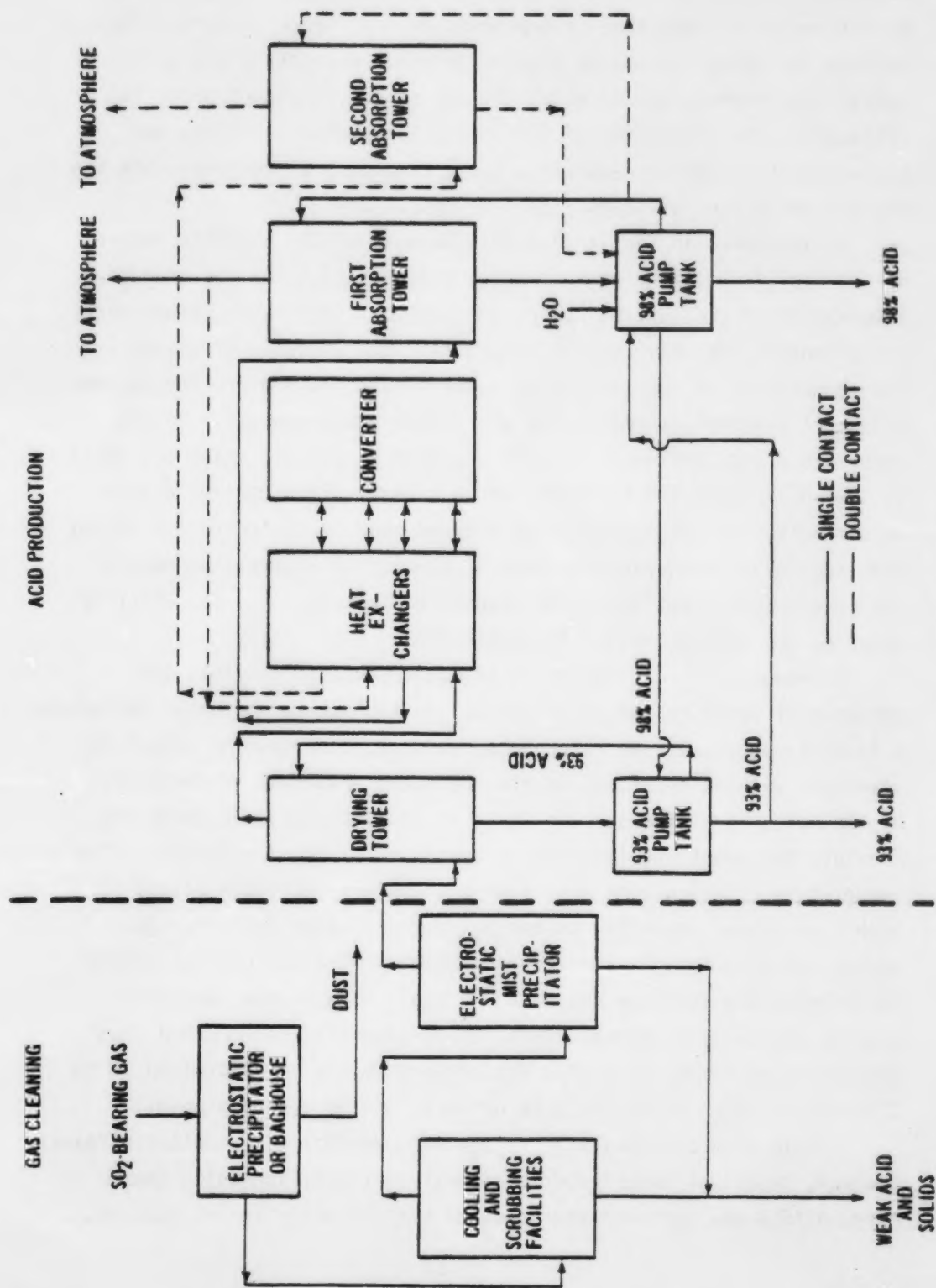


Figure 3-2. Contact Sulfuric Acid Plant

Regardless of the control device employed, the amount of achievable arsenic emission reduction is dependent on four major factors. These include the concentration of arsenic trioxide present in the gas stream, the temperature to which the gas stream is cooled prior to collection, the allocation of sufficient time between cooling and collection to allow condensable arsenic compounds to condense, and the overall collection efficiency of the control device.

As discussed in Section 3.1.1.1, because of the volatile nature of arsenic (As_2O_3), the arsenic inlet concentration and the operating temperature of the control device are critical factors in determining its potential effectiveness in controlling the emission of arsenic. The temperature of the gas stream to be treated determines the maximum amount of arsenic present in the gas stream which can exist in the vapor state and, consequently, the quantity of arsenic which can exist in the solid state and be collected in a particulate control device. As a result, the gas stream to be treated must be cooled to the extent practicable and adequate time must be allowed to ensure that most of the condensable fraction of the arsenic present is condensed prior to entering the control device for collection.

Although cooling is basic to effective arsenic control, the presence of moisture and sulfur oxides in the smelter offgases introduces a lower temperature constraint below which further cooling cannot be tolerated without incurring severe operating problems. Because SO_3 is hygroscopic, it will absorb moisture at temperatures well above the moisture dew point and form highly corrosive sulfuric acid mist. The temperature at which acid mist formation occurs (acid dew point) is highly variable, depending on the SO_3 concentration and other gas stream characteristics. Continued operation of a dry control device at or below the acid dew point could result in a severe corrosion problem due to acid attack. Thus, it is generally recommended that the operating temperature of a dry control device be maintained 10 to 25°C (20 to 45°F) above the best estimate of the acid dew point.¹¹

Little data are available on the acid dew point of smelter offgases. However, practical experience at several smelters, including the three ASARCO smelters and the Anaconda smelter prior to its closing,

indicates that operating temperatures in the range of 100°C (212°F) to 110°C (230°F) are within tolerable limits.

The quantity or concentration of arsenic in the gas stream is very important in determining achievable arsenic emission reductions. To achieve any arsenic trioxide emission reduction by condensation, the quantity of arsenic trioxide in the gas stream must be sufficiently high so that the resultant arsenic trioxide concentration at the control device operating temperature exceeds the predicted saturation concentration. If the arsenic trioxide concentration at the control device operating temperature does not exceed the predicted saturation concentration, little or no emission reduction is achievable. Conversely, if the arsenic trioxide concentration greatly exceeds the predicted saturation concentration, arsenic emission reductions approaching the overall performance capability of the control device for particulate matter can be achieved.

The effect of the overall collection efficiency of the control device on achievable arsenic emission reduction is self-evident; the higher the efficiency for total particulate matter, the higher the efficiency for arsenic.

3.1.2 Fugitive Emission Sources and Controls

Fugitive emissions may be characterized as emissions which escape directly from the process area to the atmosphere rather than through a flue or exhaust system. They result from leakage in and around process equipment and from material handling and transfer operations.

Fugitive emissions from these sources are controlled by local ventilation (i.e., use of localized hoods or enclosures) or general ventilation techniques (i.e., building evacuation) to confine and capture emissions. Once captured, the emissions may be vented directly to a particulate control device or combined with process offgases prior to collection in a control device. As with process sources, some consideration must be given to cooling prior to collection. In most instances, however, cooling occurs naturally as a result of air dilution due to infiltration and, therefore, additional equipment is not required.

Besides the use of add-on controls, fugitive emissions from some sources may be minimized or eliminated by minor process changes and

good operating and maintenance practices. A general discussion of these and other control alternatives is presented in the following subsections.

3.1.2.1. Local Ventilation. Local ventilation consists of using localized hoods or enclosures to confine the fugitive emissions at the source, and the use of induced air currents to entrain and capture the fugitive emissions and divert them into an exhaust opening.

The design of a local exhaust hood involves specifying its shape and dimensions, its position relative to the emission point, and its rate of air exhaust. The rate of exhaust is dependent on the air velocity required and on the size of the imaginary curving area of the hood. Air contaminants originating within this area are drawn directly into the exhaust opening. Methods for estimating the surface area of an exhaust hood can be found in standard references dealing with industrial ventilation. The capture velocity is the velocity of the air at the hood face or entry plane necessary to overcome opposing air currents and to capture the emission-laden air by causing it to flow into the exhaust hood.^{11,12}

Hoods can generally be classified into three broad groups: enclosures, receiving hoods, and exterior hoods. Enclosures usually surround most of the point of emission, though sometimes one side may be partially or even completely open. Receiving hoods are those wherein the air contaminants are injected into the hoods. For example, the hood for a grinder is designed to be in the path of the high velocity dust particles. Exterior hoods must capture air contaminants that are generated from a point outside the hood itself, sometimes some distance away. A canopy hood is a good example of an exterior hood.

Exterior hoods are the most commonly used hoods and are by far the most difficult to design since they are the most sensitive to external conditions. For example, a hood that works well in a still atmosphere may be rendered completely ineffective by even a slight draft through the area.

For exhaust hoods to be effective, sufficient ventilation must be applied across the space between the source and the hood so that all emissions are entrained. This involves overcoming the cross currents of indoor air which could deflect the stream of fugitive emissions

away from the hood. The ventilation rate for exhaust hoods applied to hot sources must also take into account the thermal draft that results from heat transfer from the source to the surrounding air. The exhaust rate should be as uniform as possible over the entire plane of the hood inlet. Various exhaust hood configurations are illustrated in Figure 3-3.

So-called "air curtains" can be used as complementary capture devices for local ventilation. Air curtains are basically air jets of suitable geometric configuration with sufficient momentum to resist the forces working against them and maintain their continuity across the opening they protect. For ventilation purposes, they are used as part of push-pull type systems, wherein the air jet or curtain is blown across the emission zone, forcing the emissions into an exhaust hood located opposite the air curtain slot. Typical examples of air curtain applications are shown in Figure 3-4. As indicated in Figure 3-4(a), hazardous fumes, e.g., vinyl chloride, can be contained by the use of air curtains. Dust control by air curtains is shown in Figures 3-4(b) and 3-4(c). A detailed discussion of air curtains is presented in Section 3.1.2.7.2.

The following typical fugitive emission sources at copper smelters can be controlled by local ventilation methods:

- Calcine transfer from roaster
- Matte tapping
- Slag tapping
- Converter

3.1.2.2 General Ventilation. This technique is required whenever it is not possible or expedient to use local exhaust hoods because of their handicapping operations, maintenance, or surveillance of the process or equipment; or when the local exhaust does not significantly reduce air requirements or has no worker exposure advantages.

General ventilation has historically taken the form of either natural air changes due to wind and density differences, or mechanically assisted air changes. Natural changes of air through a building in the absence of mechanical ventilation occur by the action of either of two forces, the play of wind through windows or other openings or the

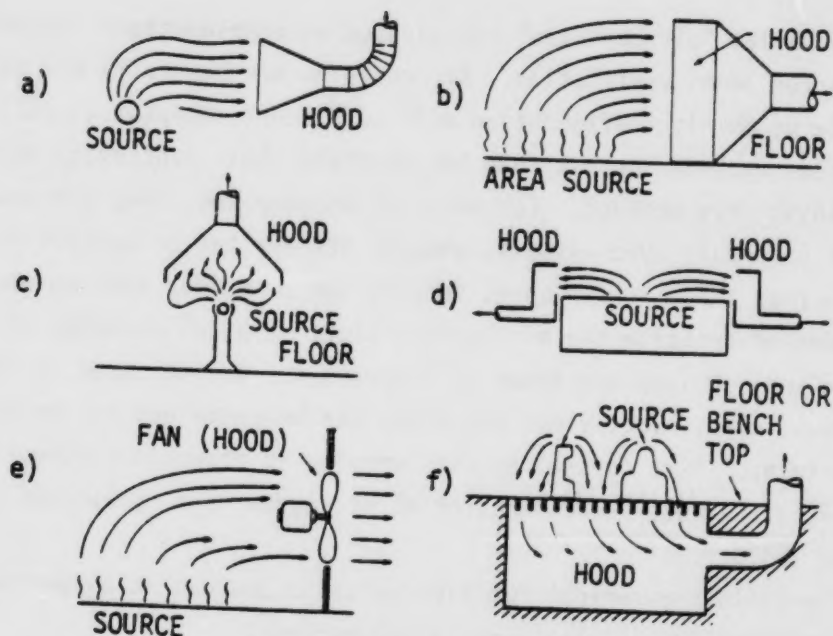


Figure 3-3. Types of Exhaust Hoods 12

NOTE: In all cases, the source of contamination is beyond the boundaries of the hood structure; hence, control action is effected by inducing velocities in the adjacent space.

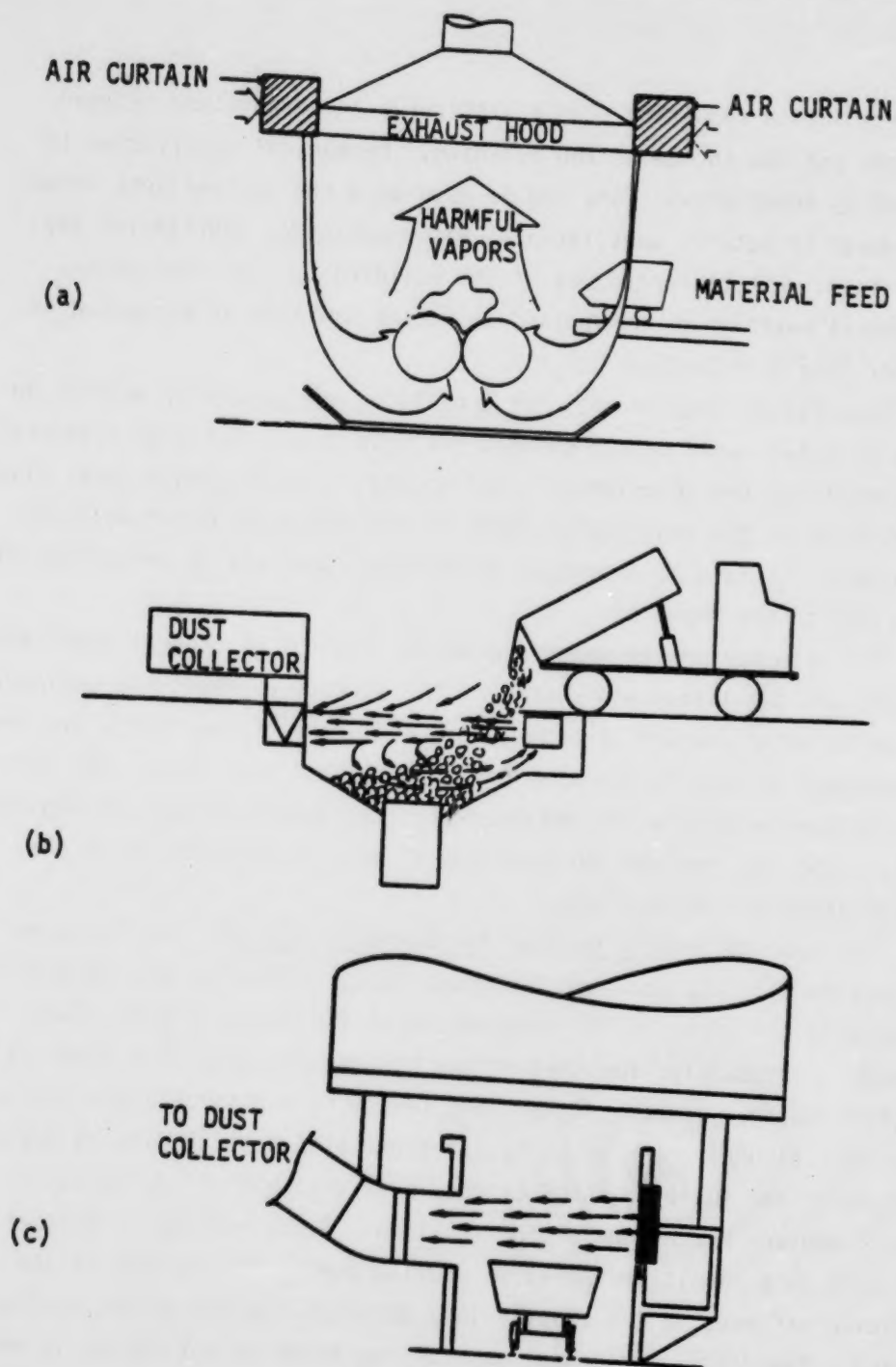


Figure 3-4. Uses of Air Curtains^{13,14}

NOTE: (a) for the control of hazardous fumes from vinyl chloride processes, (b) to control dust from a primary crusher operation, and (c) to control dust from loadout chutes.

buoyancy action resulting from a difference in temperature between outdoors and the inside of the building. Mechanical ventilation is induced by motor-driven fans and is used when the contaminants cannot be removed by natural ventilation. With mechanical ventilation the contaminants can be forced out of the building by roof evacuation. Mechanical ventilation as applied to copper smelters is discussed in greater detail in Section 3.1.2.7.

Ventilation requirements for a building are generally defined in terms of total building air changes per unit time. Although essential in determining the ventilation requirements, the air change rate, also referred to as the ventilation rate, is not the only factor which is important. It is also important to consider the rate of generation of emissions in the building.

The main factors on which successful control of general ventilation depends are the layout and siting of the sources of heat, the configuration of the building (number of spans, form and shape of the roof), and the arrangement of ventilation openings in walls and roof bays. The most satisfactory solutions are obtained when the architect and the engineer collaborate and consider the problems of natural ventilation at the design stage of the facility.

3.1.2.3 Collection Devices for Fugitive Sources. As discussed in Section 3.1.1.1, the most important factor affecting the controllability of arsenic emissions is the temperature of the uncontrolled offgas stream. Fortunately, fugitive offgas streams are generally lower in temperature than process streams and seldom have a temperature higher than 93°C (200°F). (Refer to fugitive emission test results in Appendix C.) Cooling of the fugitive offgases occurs as a result of air dilution due to ambient mixing and/or infiltration. Also, cooling is automatically achieved as a result of radiative cooling during the passage of the fugitive offgases in the usually long ductwork leading to the control device. Therefore, additional gas cooling prior to collection is not required for fugitive emissions.

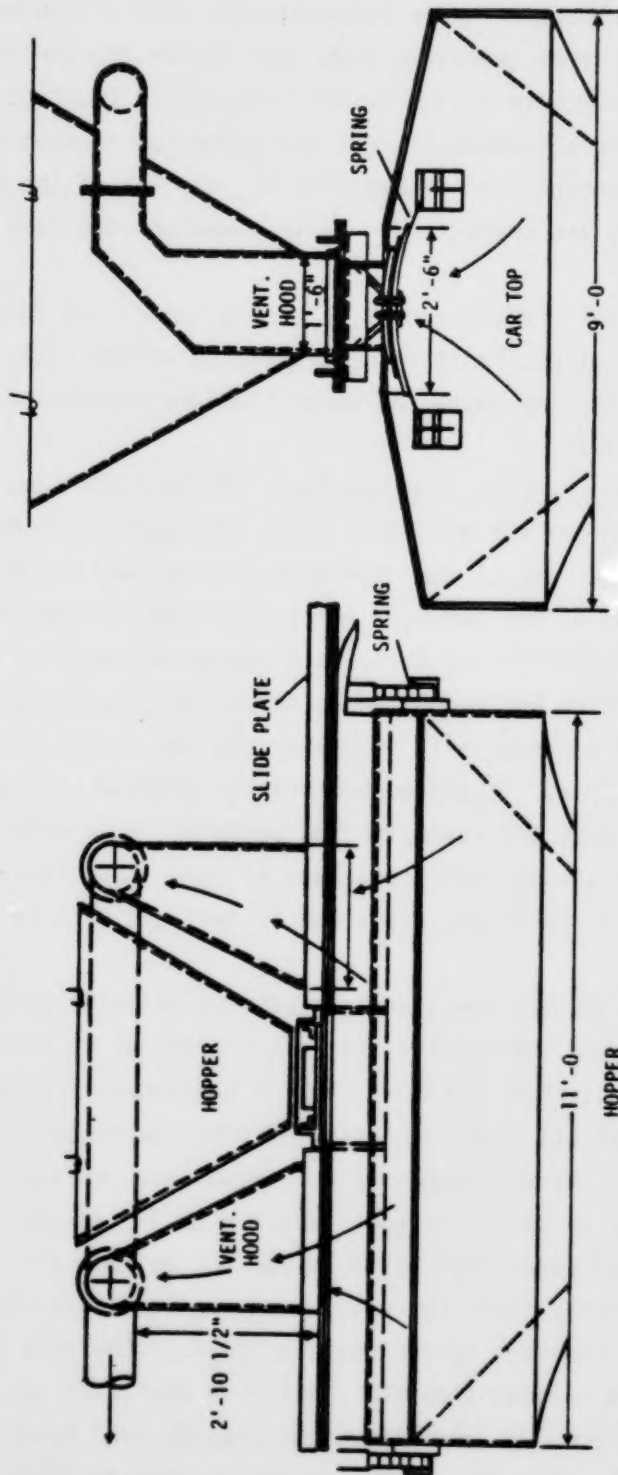
The captured fugitive emissions are usually exhausted into existing process control systems. Only two domestic copper smelters use collection devices exclusively for the control of fugitive emissions. ASARCO-El Paso

uses a baghouse to control fugitive emissions from the converter building evacuation system. Phelps Dodge-Douglas uses a baghouse to collect fugitive emissions generated from the roaster calcine discharge system. Both baghouses were tested by EPA to evaluate their performance. Results of the testing at ASARCO-El Paso are presented in Section 3.3.2.3, and in Tables C-25 through C-28 of Appendix C. Results of the Phelps Dodge-Douglas testing are presented in Tables C-53 through C-56 of Appendix C.

Although baghouses and electrostatic precipitators are currently used by smelters to collect fugitive emissions, scrubbers could also be used, but high operating costs and water handling problems make their use less desirable.

3.1.2.4 Calcine Transfer from Roaster. The multiple-hearth and fluidized-bed roaster are the two basic types of copper concentrate roasters used. In the case of the multi-hearth, the calcine hopper located at the bottom of the roaster, which drops the roaster calcine into the transfer vehicle (larry car), is a source of fugitive emissions. The use of close fitting hooding between the car and hopper outlet is difficult because of the necessity of moving the car to and from the roaster discharge hopper. Fluidized-bed roaster material transfer is carried out primarily by air conveying and secondarily by material dropout; transfer is usually well contained as long as the equipment is maintained in good condition, resulting in negligible fugitive emissions.

A schematic of the calcine transfer fugitive emission control system at ASARCO-Hayden, which is essentially identical to the one at ASARCO-Tacoma, is presented in Figure 3-5. A continuous flat apron strip nearly 0.6 m (2 ft) wide is mounted directly below the row of multi-hearth roasters at the hopper exits. Below each roaster, in the apron, there are two ports connected to a 0.5 m (1.5 ft) wide duct. A matching leaf spring-loaded flat apron is mounted on the larry car, which is driven directly below the roaster and in line with the matching holes on the apron connected to the roaster hopper. One hole is used for transferring the calcine from the roaster to the larry car. The other holes are connected to vent lines which go to vent hoods with their own individual draft fans (a single fan is used at ASARCO-Tacoma).



NOTE: CAR TOP AND HOOD - 18 GA. C.R.S.

FRONT ELEV.

SIDE ELEV.

Figure 3-5. Spring-Loaded Car Top and Ventilation Hood, ASARCO -Hayden

Each draft fan has a capacity of approximately $142 \text{ Nm}^3/\text{min}$ (5,000 scfm). The captured fugitives are then combined with the roaster process gases and treated in a baghouse.

In addition to the local hooding and ventilation applied directly at the calcine hopper discharge point, at ASARCO-Tacoma, the calcine hopper area has been enclosed to form a tunnel-like structure which is ventilated. The ventilated enclosure, coupled with the local hooding and ventilation applied at the actual calcine discharge point, is very effective in capturing fugitive emissions during calcine transfer operations. During visual observations, no fugitive emissions were observed escaping from the tunnel-like enclosure.¹⁵

3.1.2.5 Matte Tapping. Reverberatory furnaces may have up to four matte tap holes, two on each side of the furnace. Matte is tapped from one hole at a time and conveyed through troughs or launders into 4.9 to 9.2 m^3 (175 to 324 cubic feet) ladles. Typically, fewer than 30 taps per furnace are made each day, with each tapping operation taking 5 to 10 minutes. In electric furnaces there are generally four matte tap ports. Normally, only one matte tap port is in use at a time.

Copper matte from the furnace port travels through a launder which directs the flowing matte to a point where it can be collected in a large ladle. Emissions are observable from the point of the matte leaving the furnace to the point where it settles in the ladle.

Matte tap ports and launders in most smelting furnaces have hooding systems. Tap port exhaust hoods may be of any shape, as long as they are designed to be close to and cover as much of the emission area as possible. Launder hoods generally consist of covers mounted on the launder in sections to allow manual removal for launder cleaning.

Schematics of a matte tapping fugitive emission control system used at the ASARCO-Tacoma smelter are presented in Figures 3-6 and 3-7. The matte tap hood has a 1.2 by 1.2 m (4 by 4 ft) square cross-section and is located less than 0.9 m (3 ft) above the tap hole. The ducts connecting the matte tap exhaust hoods to the 1.2 m (4 ft) diameter main duct are approximately 0.6 m (2 ft) in diameter. During a tap, $283 \text{ Nm}^3/\text{min}$ (10,000 scfm) is exhausted at the tap hole

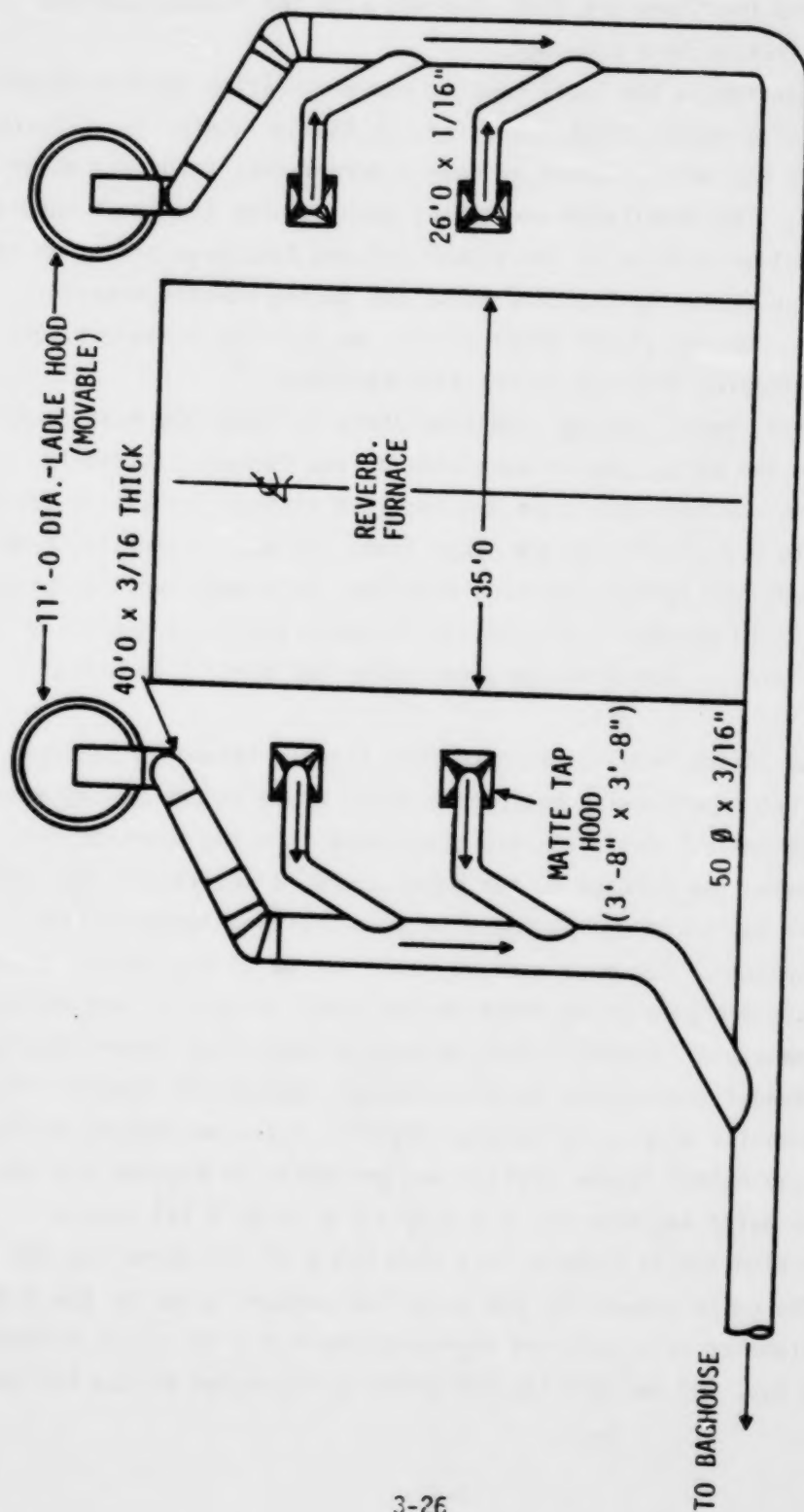


Figure 3-6. Matte Tapping Fugitive Control System (Plan View),
ASARCO-Tacoma

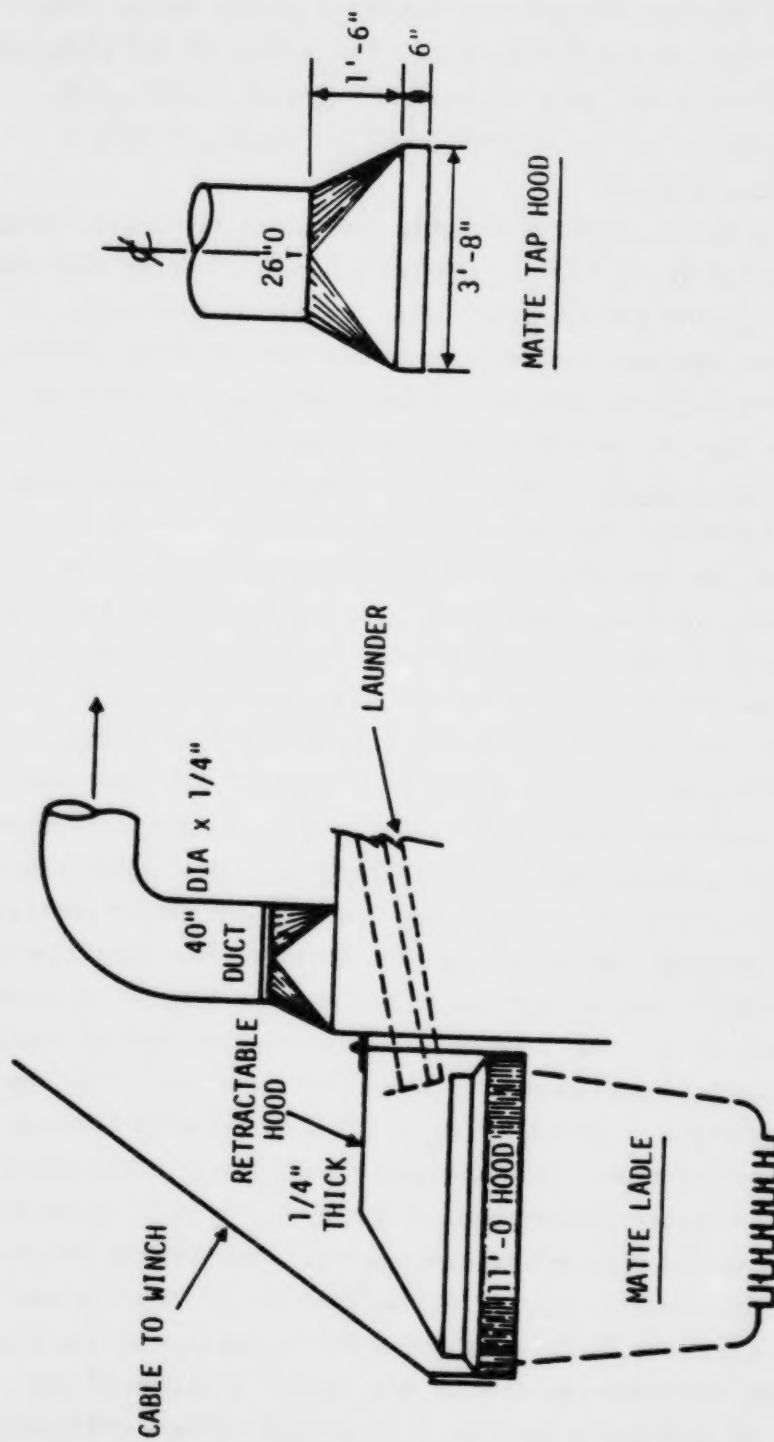


Figure 3-7. Matte Tapping and Ladle Hoods

hood and $850 \text{ Nm}^3/\text{min}$ (30,000 scfm) is exhausted at the ladle. The covered launder is 3 to 6 m (10 to 20 ft) long, 0.6 m (2 ft) wide, and approximately 0.3 m (1 ft) deep. The launder covers (Figure 3-8) range in size from 0.6 to 1.5 m (2 to 5 ft) in length and have a semicircular cross-section.

A 3.4 m (11 ft) diameter retractable ladle hood is used to capture emissions generated at the ladle. The ladle hood is lowered over the ladle prior to tapping and is raised after the tap is completed.

From testing and observations made at the ASARCO-Tacoma smelter, the matte tapping fugitive emission capture system was observed to achieve greater than 90 percent capture efficiency.¹⁵

3.1.2.6 Slag Tapping. Generally, reverberatory furnaces have just one slag tap hole. Typically, slag is tapped an average of 30 times per day for approximately 10 to 20 minutes per tap. In electric furnaces there are usually two slag tap ports with one slag tap port in use at a time. The duration of a slag tap is normally 10 minutes. The slag flows from the tap port, down an inclined launder, and into one or more slag pots. The slag pots/ladles at various smelters range in capacity from 2.8 to 17 m^3 (100 to 600 cubic feet).

Fugitive emission capture techniques for slag tapping operations are very similar to those used for matte tapping. Local exhaust hoods are used over slag tap port areas. Slag launders are either partially or completely covered. Design volumes for exhaust hoods vary from one smelter to another, ranging from 566 to $850 \text{ Nm}^3/\text{min}$ (20,000 to 30,000 scfm).

A schematic of the slag tapping fugitive emission control system used at the ASARCO-Tacoma smelter is shown in Figure 3-9. Slag tap hoods are pyramidal in shape, having a 1.2 m by 2.4 m (4 ft by 8 ft) rectangular cross-section. They are less than 0.9 m (3 feet) above the tap hole. A larger exhaust hood, 2.4 m by 4.3 m (8 ft by 14 ft), is situated above the slag pot transfer point. Each launder is covered with fixed hoods. During tapping, $142 \text{ Nm}^3/\text{min}$ (5,000 scfm) is applied at the tap hole and $566 \text{ Nm}^3/\text{min}$ (20,000 scfm) is applied at the slag pot. Emissions along the launder run are vented to either of the above hoods. As with matte tapping, a 90 percent capture efficiency should be achievable.

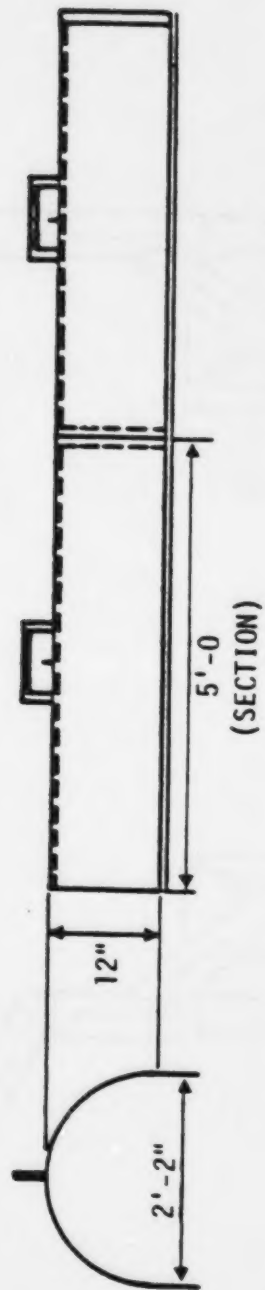


Figure 3-8. Laundry Cover

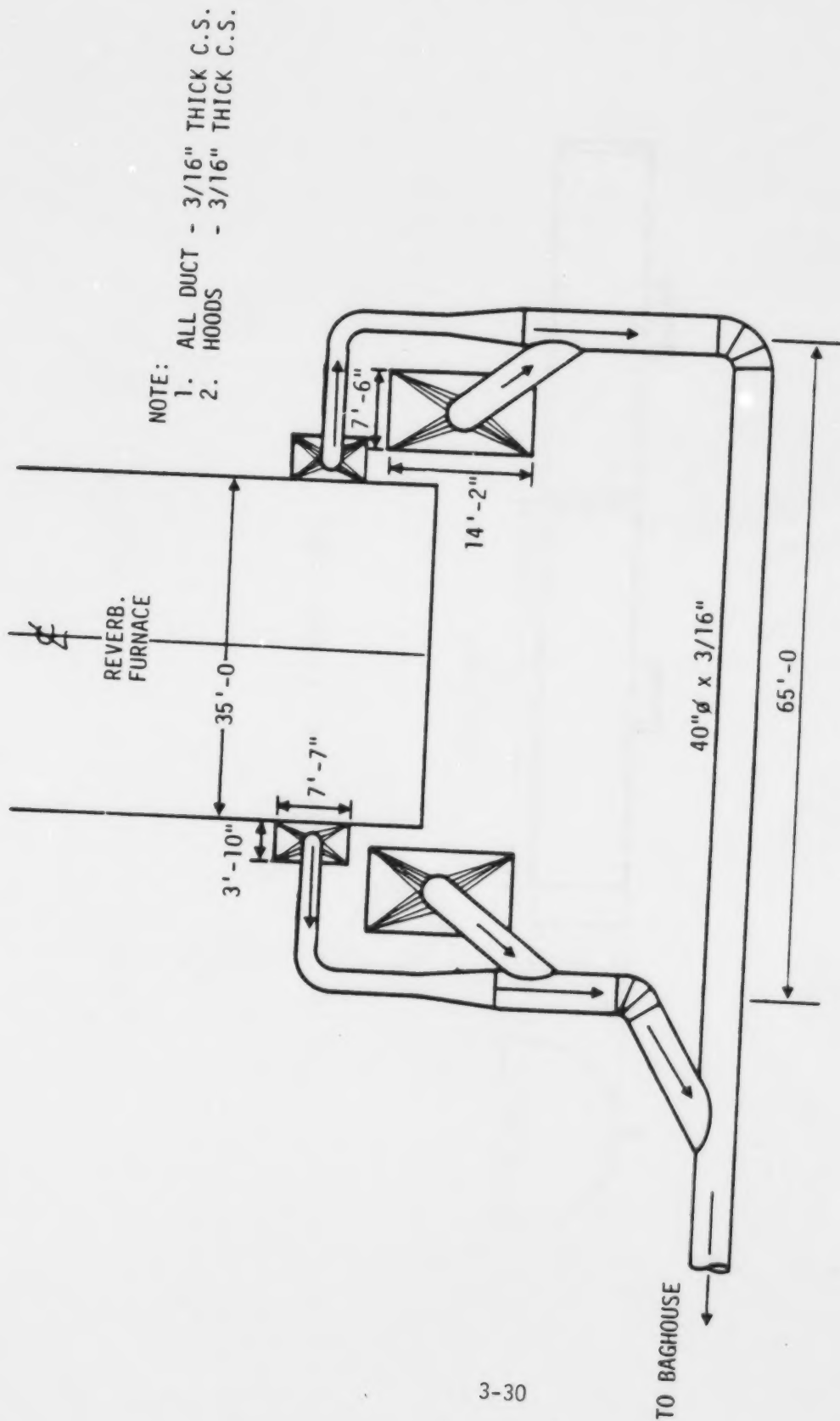


Figure 3-9. Slag Tapping Fugitive Control System (Plan View),
ASARCO-Tacoma

3.1.2.7 Converter Operations. Primary converter hoods capture process emissions during converter blowing periods, except for some emissions that escape due to primary hood leakage. However, during converter charging, skimming, or pouring, the mouth of the converter is no longer under the fixed primary hood, and extensive quantities of fugitive emissions escape capture by the primary hood.

Another source of fugitive emissions during converting occurs during the converter holding mode. This occurs under normal smelting operations when material, either slag or blister, cannot be immediately transferred from the converters to the ladles. During this period the generated emissions are not evacuated by the primary hood.

There are currently three basic alternative control techniques used to capture fugitive emissions during converting. They are: (1) secondary mechanical hoods; (2) air curtain secondary hoods; and (3) general ventilation/building evacuation.

3.1.2.7.1. Secondary mechanical hoods. In normal practice, primary converter hood systems are used only when the converters are in the blowing mode. At some smelters, secondary mechanical hoods are being used to capture emissions generated from the converter mouth during the other modes, such as charging, skimming, holding, and pouring. The flow rates handled by these hoods range from 700 to 2,400 Nm³/min (25,000 to 85,000 scfm).

There are three major types of secondary mechanical hoods:

1. Fixed type - Attached to the primary or uptake hood, and currently used at Phelps Dodge-Ajo, Phelps Dodge-Hidalgo, Phelps Dodge-Morenci, and Kennecott-Utah.

2. Swing-away type - This type is being used at the Saganoseki smelter in Japan and consists of a swing-away type hood used as a deflector and a retractable type secondary hood just above it.

3. Mechanical type - This is a combination hood system utilizing a fixed hood, movable hood, gate hood, and swing-away hood. This system is a conceptual design system for converter fugitive emissions control.¹⁶

Domestic copper smelters are using the fixed type of secondary hooding to control fugitive emissions from converters. A typical

converter secondary hood configuration of the fixed type is shown in Figure 3-10. These hoods are approximately 3 m (10 ft) long, 6.4 m (21 ft) wide, 1.7 m (5.5 ft) high and are affixed to the upper front side of the converter primary uptake hoods. Testing and observations made at existing copper smelters utilizing fixed converter hoods indicated that their effectiveness was only marginal.¹⁷

The swing-away type converter hood, sometimes called a deflector converter hood with a retractable secondary hood, is used at Japan's Saganoseki smelter. The hood was observed to be very effective during the blowing, slagging, and pouring of blister copper.¹⁸ During charging of matte or rabbling, capture of the secondary emissions depended solely on the retractable hood portion of the device.

The converter mechanical secondary hood system shown in Figure 3-11 is a conceptual design developed by an EPA consultant.¹⁹ This system uses a fixed hood in combination with a movable hood, a gate hood, and a swing hood. The elliptical fixed hood is made of steel and is attached to the primary uptake hood of the converter. Its opening is situated in a manner to avoid the hook of the overhead crane during converter operations. The upper end of the fixed hood is attached to the smoke plenum, which leads to dust bins on each side of the converter.

The elliptical movable hood (refer to Figure 3-11) is made of steel and fits over the fixed hood. It has its own track of movement. In the retracted position, this hood does not extend further, horizontally, than the fixed hood. In the extended position, it mates with the lip of the fixed hood to provide continuity of ducting for secondary emissions.

The elliptical gate hood fits under the fixed hood in the retracted position. In the extended position, the gate hood continues ducting of the secondary emissions to the movable and fixed hood.

The frustum-shaped swing hood can be rotated 180 degrees. The width at the top is the same as that of the mouth of the gate hood. This hood is made of steel with a castable refractory lining. Its pillar-mounting is motorized. In the retracted position it is clear of the aisle and slightly behind the converter.

Retrofitting the mechanical secondary hood system to an existing smelter could pose a difficult problem. The operational safeguards

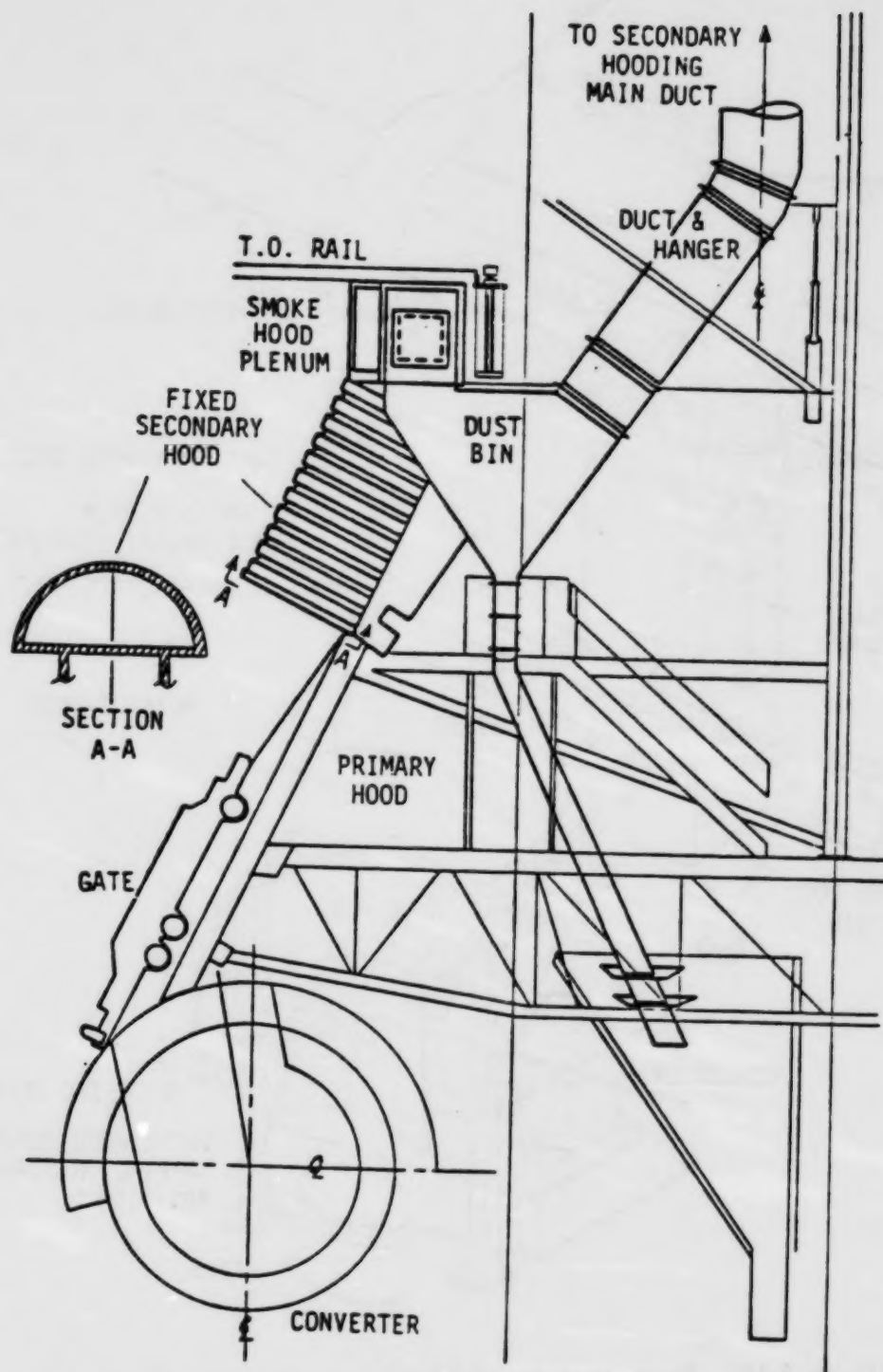


Figure 3-10. Typical Converter Fixed Secondary Hood

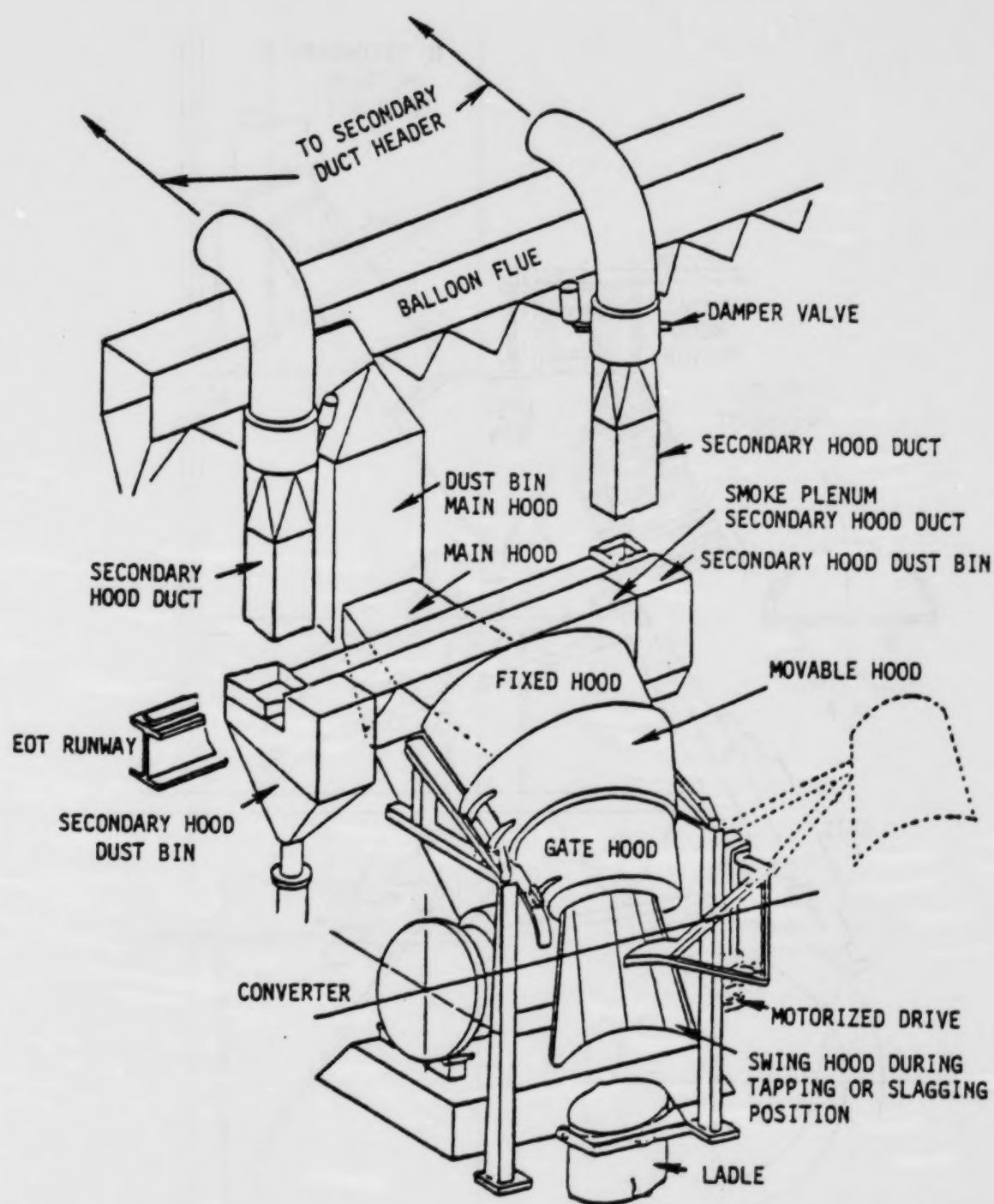


Figure 3-11. Conceptual Design for Converter Mechanical Secondary Hood System

that would be required to operate it with a minimum number of breakdowns, delays, and damage would require close supervision and extensive effort. On the other hand, the maintenance and operation of the relatively inefficient fixed converter secondary hood system currently being used at domestic smelters and the swing-away converter secondary hood system, as used in Japan, are quite simple.

The efficiency of fixed converter secondary hoods is generally dependent upon the distance of the hood from the emission source and on the capture and face velocity created by the fan at the mouth of the fixed hood. Conversely, maintenance and durability are enhanced as the hood is moved farther from the converter mouth. The capture effectiveness of the fixed converter secondary hoods applied at the Phelps Dodge-Ajo and Phelps Dodge-Hidalgo smelters was judged to be low.¹⁶

The swing-away type of secondary converter hood again causes clearance problems with the crane hook and cables during collar pulling or matte additions. Also, rugged drive mechanisms are needed for the operation of the swing-away hood and added time is needed to complete pouring and skimming operations due to the time involved in the retraction of the swing-away hood to allow crane access to the ladle. However, good fugitive emission control is obtained during pouring, blowing, and slagging. During matte addition or rabbling, the capture efficiency is similar to that of a fixed hood.

Since the converter mechanical secondary hood system combines a fixed and a swing-away hood in combination with a movable hood, it should be more effective than either a fixed hood or swing-away hood used alone. The capture efficiency of the converter mechanical secondary hood system during charging, pouring, skimming, and blowing is estimated to be 40, 85, 70, and 85 percent, respectively.²⁰ Assuming a typical converter operation to consist of 80 percent blowing, 15 percent charging, and 5 percent skimming and pouring, an overall average capture efficiency for the mechanical secondary hood system is calculated to be approximately 80 percent.

3.1.2.7.2 Air curtain secondary hoods. Another method of controlling fugitive emissions from copper smelter converting operations involves

the use of an air curtain system along with a secondary hood system. An air curtain secondary hood capture system has been installed on a domestic primary copper smelter (see below), and such systems are being used abroad^{14,21,22,23} and in other U.S. industries.²⁴

As discussed in Section 3.1.2.1, an air curtain is a suitably shaped air jet with sufficient momentum to resist the forces of fugitive gas streams working against it and to maintain its continuity across the opening it protects. Figure 3-12 shows a schematic diagram of an air curtain system controlling converter fugitive emissions. Consideration in air curtain design must be given to secondary or entrained flows which start forming as the air curtain jet stream leaves its slot or nozzle. As the entrained flows become fully mixed with the air curtain jet stream some distance from the nozzle, the hot or cold secondary flows are carried from one side of the air curtain jet stream to the other where they are ducted for suitable discharge. The greater the entrained flow, the greater the energy loss of the jet. To minimize energy loss, a relatively thick, slow moving jet stream with a large air volume is required. A basic rule in the design of air curtains is to use the thickest and lowest velocity air stream to be projected across the shortest dimension of the opening. Air curtain design methods are discussed in references 14, 25, and 26.

The air curtain system being used at the Onahama and Naoshima primary copper smelters in Japan is shown in Figure 3-13. The capture/shielding device includes two steel plate partitions, one on each side of the converter. The air jet is blown from a slot at the top of one of the plates across the opening to provide a sheet or curtain of air that prevents fugitive emissions from escaping. The other plate is equipped with an exhaust hood. The opening allows the crane cables to move into position above the converter mouth.

A propeller fan is used to push the air through an elongated slot on one side and a backward inclined fan provides suction on the opposite side to pull in both the fugitive gases and the push air. Captured gas passes through steel ductwork to a baghouse. The combined temperature of the converter fugitive gases with 100 percent of the push air

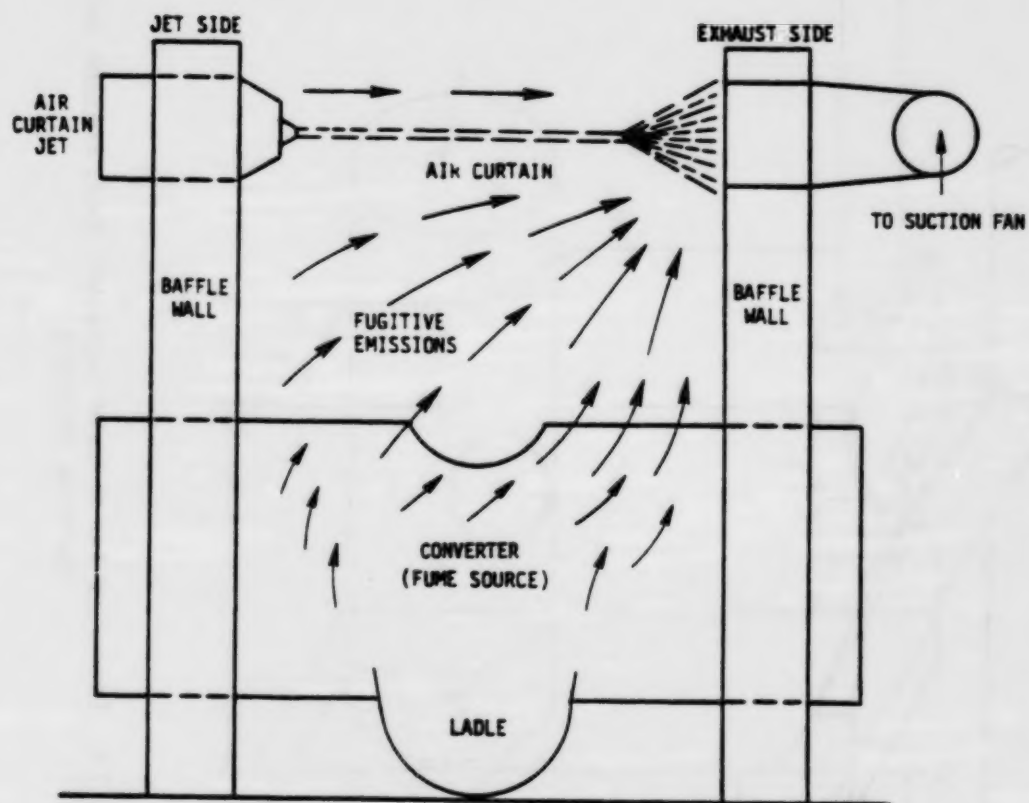


Figure 3-12. Converter Air Curtain Control System

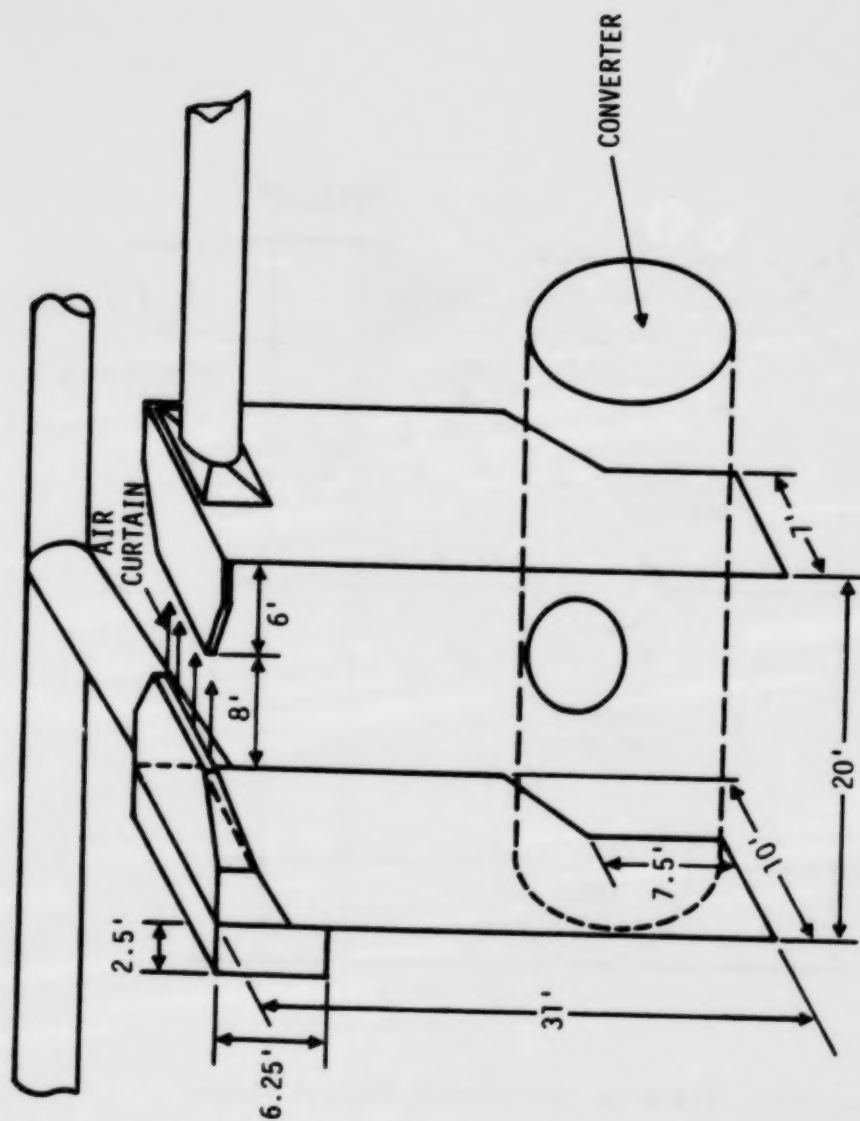


Figure 3-13. Converter Air Curtain Secondary Hood, Onahama and Naoshima Smelters

entering the ductwork on the pull side of the air curtain is approximately 80°C (180°F), which makes gas cooling prior to the control device unnecessary.

The inlet air forming the air curtain above the converters at the Naoshima smelter has a flow rate of approximately 600 Nm³/min (21,000 scfm). The exhaust hood on the opposite side pulls in approximately 1,000 Nm³/min (35,000 scfm) of gas to the main system. The capacity of the total pull system at this smelter is three times this value, or 3,000 Nm³/min (105,000 scfm), to accommodate the operation of three hoods at a time. According to Naoshima authorities, the collection efficiency of these hoods for fugitive emissions is approximately 90 percent.²⁷

The Tamano copper smelter in Japan uses a differently designed air curtain system along with a fixed hood, which is essentially a total enclosure, for controlling fugitive emissions from each of its three converters (usually one converter is operated at a time.) A sketch of the air curtain system installed at the Tamano smelter is shown in Figure 3-14.²² The enclosure has two front doors and a movable roof which is slightly inclined toward the front. The air curtain duct (slot hood) is located at the top of the enclosure level at a position to push air from one side of the converter to the other. Ambient air is supplied by a ground fan rated at 1,200 Nm³/min (41,000 scfm). Two ventilation points (offtakes) are located at the inside wall of the enclosure for capture of fugitive emissions; one is for dilute SO₂ gas and the other is for high concentration SO₂ gas. The inlet of the ductwork for high SO₂ gas is located near the converter mouth at a level below the other ductwork for dilute SO₂ fugitive gas. For convenience, the inlet of this ductwork is shown at the top of the roof in Figure 3-14.

Subjective evaluation of the air curtain secondary hood by visible observation at the Tamano smelter indicates the system to be at least 90 percent effective in controlling fugitive emissions.²²

ASARCO's Tacoma facility recently installed a prototype air curtain secondary hooding system to control fugitive emissions from their No. 4 converter. In this system, walls are erected to enclose the sides and the back of the area around the converter mouth, with a

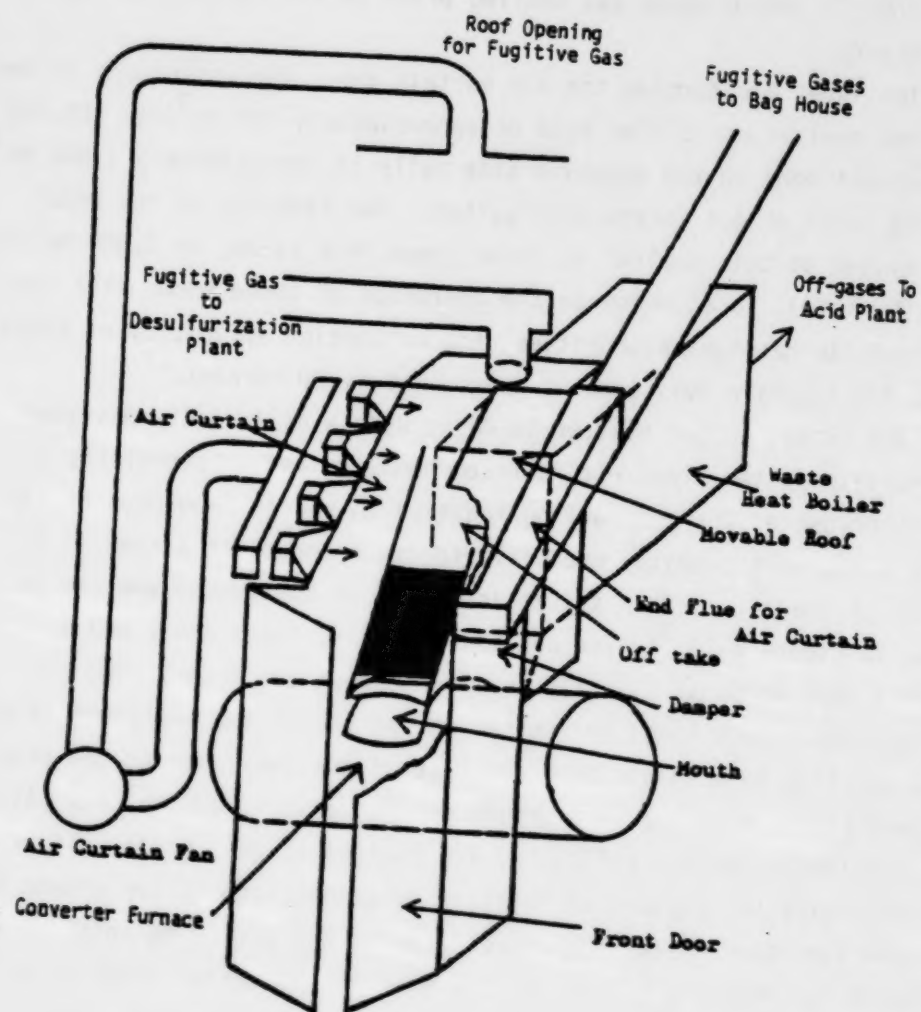


Figure 3-14. Air Curtain System at the Tamano Smelter

portion of the enclosure back wall formed by the primary hood. Openings at the top and in the front of the enclosure allow for movement of the ladle and the overhead crane cables and block. The edges of the walls which contact the primary hood and the converter vessel are sealed to contain the emission plume.

When the converter is rolled out for charging or skimming, the gate on the primary hood is moved up and away from the converter mouth to provide clearance for the overhead crane and ladle. As noted previously, significant amounts of dust-laden fumes (fugitive emissions) escape the primary hood system during these modes of the converter cycle. Heavy fugitive emissions are generated during the roll-out and roll-in modes, when charging (including cold additions), slag skimming, and blister copper pouring are taking place. The heaviest emissions occur during the actual rolling out of the converter because the injection of blowing air continues during roll-out until the molten bath is below the tuyeres to prevent plugging by cooled material. During these periods of operation, the air curtain is utilized to capture most of the emissions which would otherwise escape the primary system.

Air volume control for the system is regulated automatically by dampers in the air curtain jet, the exhaust duct, and the induced draft fan. The dampers are manually set for a predetermined exhaust-side flow and, when placed in the automatic control position, are activated by movement of the primary hood and converter. When the primary hood is lifted and the converter is rolled out, the system switches to a high flow mode to control the heavy fugitive emissions generated during roll-out activities. At the completion of the converter roll-out operations, the converter is rolled in and the primary hood is lowered over the converter mouth. At this point, the system switches to a lower flow volume which is maintained during blowing and holding periods.

The gases that are captured by the air curtain system are treated in an ESP for particulate removal before being passed to the atmosphere through the main stack.

Design data for the ASARCO system are summarized in Table 3-4.

Table 3-4. SUMMARY OF DESIGN DATA FOR THE ASARCO-TACOMA CONVERTER
SECONDARY HOODING/AIR CURTAIN SYSTEM²⁸

Mode of operation	Air Curtain Push Rate, Actual m ³ /min	Main Offtake Evacuation Rate, Actual m ³ /min
Matte charging	510 (18,000 acfm)	2,322 (82,000 acfm)
Blowing	- ^a	1,700 (60,000 acfm)
Slag skimming	510 (18,000 acfm)	2,322 (82,000 acfm)
Holding	510 (18,000 acfm)	850 (30,000 acfm)
Worst conditions ^b	1,020 (36,000 acfm)	4,644 (164,000 acfm)

^a Air curtain will not be used during the blowing mode.

^b Worst conditions would consist of either (1) two converters being charged simultaneously or (2) one converter being charged while another was being skimmed.

EPA conducted a program to evaluate the capture effectiveness of the ASARCO-Tacoma air curtain secondary hood system in January 1983.²⁹ This program included arsenic and total particulate sampling, a gas tracer study to determine the system's capture efficiency during specific modes of converter operation, and observations of visible emissions to assess the system's effectiveness. The results of this program are presented in Section 3.3.2.2.

3.1.2.7.3 Building evacuation. As noted previously, ventilation requirements for a building evacuation system are generally defined in terms of air changes per unit time. The rate of air change method estimates are based simply on room volume and do not consider the rate of evolution of the contaminant, the number of heat sources, or the natural draft due to building configuration. For example, a general ventilation installation designed by the rate of air change method can, under some conditions, actually cause the contaminant to be spread throughout the building, thus increasing the volume of dilution air required to maintain hygienic conditions. This occurs when the distribution of the ventilation air supply is poorly controlled. Uncontrolled air flowing into a building, due to negative pressure in the building or because of poorly designed air supply distributors, may not only cause recirculation of the contaminant, but also upset the local ventilation systems. It is, therefore, important that the amount of air, the location of its entry into the building, and its direction be controlled. For example, Figure 3-15 shows a controlled air supply which results in a convective flow from a heat source (such as a ladle of molten metal) rising to be exhausted through a roof ventilator. Figure 3-16 shows an uncontrolled air supply which results in a disrupted rising plume and recirculation of the contaminant throughout the building.

Natural air changes take place when hot air from the ground level heat sources rises due to its buoyancy. If, however, there exists a point within the building where the temperature of the surrounding air is equal to that of the rising column of hot air, buoyancy is lost. Therefore, natural air changes will take place only if the temperature of the rising column of hot air is high enough to maintain the buoyancy

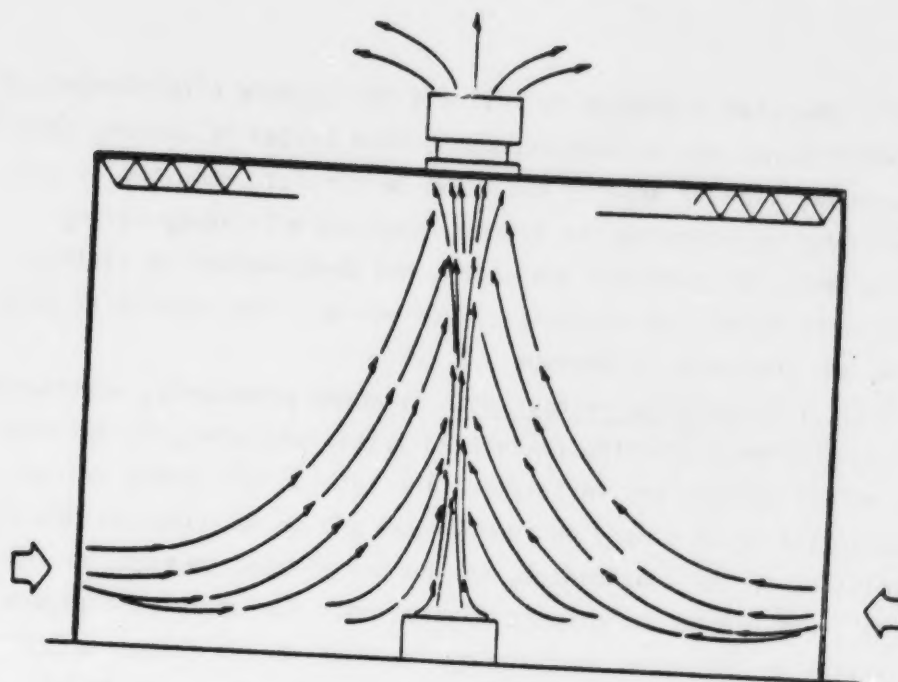


Figure 3-15. Controlled Airflow from a Heated Source³⁰

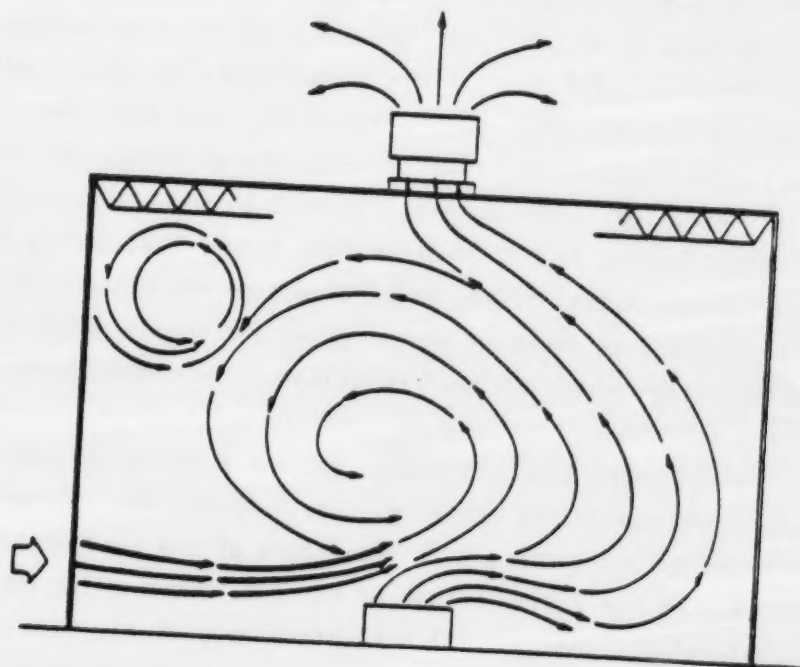


Figure 3-16. Uncontrolled Airflow from a Heated Source³⁰

of the column until it is discharged through the roof monitors. In most hot metal workshops this is, however, not the case. Hot air pools of some depth are formed under the building roofs. As a result, air entering the building will at times mix turbulently with pools of contaminated air and transport it downward to the occupied levels near the floor.

The concept of controlled ventilation is being employed at the ASARCO-El Paso smelter to capture emissions from the converter aisle. Several modifications (area isolation, vent location, air flow control, etc.) were made in order to implement this control measure at the facility. The present building evacuation rate is 16,800 Nm³/min (600,000 scfm). This corresponds to an air change rate of 18 changes per hour. Although it is impossible to quantify, the building evacuation system at El Paso, when properly operated and maintained, is believed to be capable of achieving 95 percent capture. Particulate emissions contained in the building ventilation gases are controlled by a baghouse. EPA has performed tests on this baghouse; the results are provided in Section 3.3.2.3, and detailed test summaries are presented in Appendix C. Although the building evacuation system at ASARCO-El Paso should be capable of achieving 95 percent capture, the capture effectiveness actually being achieved is substantially less. Severe operating problems with this system have been encountered, which have led to unacceptable buildups of arsenic, lead, and heat in the building.³¹ Worker exposure to airborne arsenic and lead has continuously exceeded the concentration limits set by the Occupational Safety and Health Administration (OSHA) (10 µg/m³ for arsenic, 50 µg/m³ for lead). In an attempt to alleviate the situation, the company has increased the openings in the building and are presently operating roof ventilators which discharge directly to the atmosphere. The roof ventilators were originally installed for emergency use only in the event of a power failure. The company is currently investigating the use of local ventilation methods (including converter secondary hoods) for use at its El Paso facility.

3.1.2.8 Anode Furnace. Anodes are fire refined directly from molten blister copper at all domestic copper smelters. Fire refining

is carried out in rotary-type refining furnaces resembling Pierce-Smith converters or in small hearth furnaces. The rotary-type furnace is used at 14 of the 15 existing smelters. ASARCO-Tacoma is the only domestic smelter which employs hearth-type anode furnaces.

Fugitive arsenic emissions from anode furnaces contain little arsenic since most of the arsenic has been eliminated in earlier processing steps.

ASARCO-Tacoma is the only domestic copper smelter capturing arsenic emissions from anode furnaces. Emissions from the hearth-type anode furnaces at ASARCO-Tacoma are siphoned off and conveyed to an ESP for collection.

A swing-up type hood is used for the control of fugitive emissions from the rotary-type anode furnaces used in Japan. A schematic of such a hood is presented in Figure 3-17. This hood has a flexible duct approximately 0.7 m (2.25 ft) in diameter connected to an arc-shaped hood. The hood is approximately 4 m (13 ft) wide and 3 m (10 ft) long. The quantity of dilution air required to cool the gases is a function of the position of the hood above the anode furnace mouth. For an anode furnace temperature of 982°C (1,800°F), the quantity of dilution air required to reduce the temperature to 121°C (250°F) will be 198 Nm³/min (7,000 scfm). The collection system is designed for 425 Nm³/min (15,000 scfm) for one anode furnace under these conditions.

The emissions captured by the swing-up hood occur during the oxidizing and reducing blows. The emissions collected during these blows constitute the majority of the emissions generated. Some emissions escape during the charging of blister from the ladle and during the pouring of refined copper from the anode furnace, since the mouth of the furnace during these operations is not under the hood system; these emissions, however, are comparatively small.

3.1.2.9 Dust Transfer, Handling, and Conveying. Dust transfer, handling, and conveying practices vary from smelter to smelter. However, the dust transfer from control devices and smelter flues is common practice at all smelters.

Dust collected by an electrostatic precipitator drops into a storage hopper beneath the unit. A collecting conveyor, contained in dust-tight housing, transfers this dust to a storage bin from which

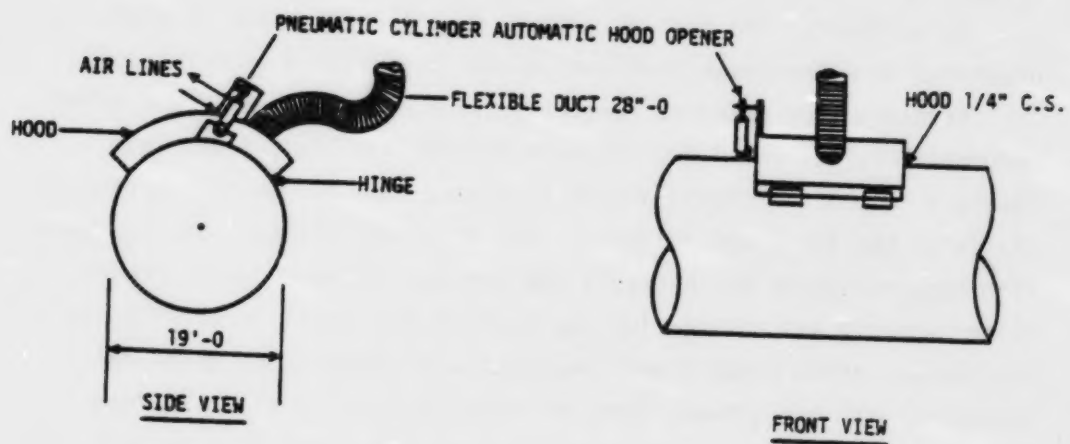


Figure 3-17. Anode Furnace Movable Hood

dust may be withdrawn as desired. These bins are usually equipped with dust level indicators. Discharge from the storage hopper is usually through a dust-tight connection to surface transportation units. Normal practice is to distribute the dust on smelter feed beds where it is sprayed with water and covered by damp concentrates or precipitates and other furnace charge materials.

Dust collected by a baghouse drops into a holding hopper during the shaking cycle and is removed through a double gravity gate or rotary valve and into an enclosed collector conveyor (generally of the screw type), which in turn discharges into a closed storage bin. Depending on the nature of the collected dust and its metallurgical values, it is either conveyed to the charge mixing area or is discarded.

In scrubbers, the dust is removed as a slurry, which is then dewatered in a thickener or filter and/or passed to a settling pond.

Offgases from roasters, smelting furnaces, converters, and other pyrometallurgical units are conveyed through air-tight flues and chambers to their ultimate dispersal point. The coarser dusts tend to settle in the flues and chambers. All flues and chambers are equipped with hoppers spaced at intervals underneath. These hoppers provide surge capacity and storage for the settled dust until it is withdrawn. Previously, these hoppers were equipped with plain swing gates for discharge onto the ground, into railroad cars, or to other surface conveyance equipment. Naturally, there was some dust loss by this method. Presently, these hoppers are equipped with discharge gates which usually automatically feed into screw or drag type collector conveyors for storage in a central receiving bin. The dust is then conveyed to receiving points. Flue dust, however, is a coarser material and may be dumped directly onto wet feed belts or conveyed to a desired location by pneumatic conveyors. Waste heat boilers and crossover flues present special problems because the dust from the smelting furnace is at high temperature and builds up in fusions and large accretions. These must be removed by manual means, water-bomb lances, soot blowers, fluxing, sand blasting, slugger guns, or a combination of methods. Due to the various sizes of materials dropping into the boiler ash pits, this material is handled and transported by conventional surface vehicle conveyance and is usually passed through a smelter flux crushing system.

3.2 PERFORMANCE CAPABILITIES OF ALTERNATIVE CONTROL TECHNIQUES FOR ARSENIC AND TOTAL PARTICULATE EMISSIONS

In order to evaluate the emission control capabilities of alternative control techniques for arsenic emissions and total particulate, EPA conducted emission measurements and made visual observations at several smelters including the ASARCO-Tacoma smelter. This section discusses the results of these emission measurements and presents conclusions regarding the performance capability of each of the control techniques evaluated for process and fugitive emission sources.

3.2.1 Process Control Systems

3.2.1.1 Baghouses. Tests were performed at the ASARCO-Tacoma and Anaconda* smelters to evaluate the performance of baghouses in controlling arsenic emissions. Tests were also performed at the Anaconda smelter to evaluate the performance of the baghouse in controlling total particulate emissions. Two baghouses were sampled at ASARCO-Tacoma and one at Anaconda.

3.2.1.1.1 Baghouses (ASARCO-Tacoma). Simultaneous inlet and outlet arsenic emission measurements were performed by EPA across the baghouse serving the multi-hearth roasters at ASARCO-Tacoma.

Sampling at the inlet was performed in the duct carrying emissions from the roasting process in four 10 cm (4 in.) ports on top of the flue. The gas leaving the roaster baghouse was sampled approximately 305 m (1,000 ft) downstream from the baghouse. Three tests were performed at each location. The results are summarized in Table 3-5.³²

As indicated, the average arsenic inlet concentration and corresponding mass rate were 288 mg/Nm^3 (0.126 gr/dscf) and 87 kg/hr (191 lb/hr), respectively. The outlet arsenic loading was 0.9 mg/Nm^3 (0.0004 gr/dscf), and the mass rate was 0.3 kg/hr (0.6 lb/hr). The average arsenic removal efficiency for this unit, as indicated by these results, was 99.7 percent.

Simultaneous inlet and outlet arsenic emission measurements were also conducted at the baghouse used to treat a combination of offgases from the arsenic production facilities at ASARCO-Tacoma. These facilities

*No longer in operation.

Table 3-5. ARSENIC PERFORMANCE DATA FOR THE
ROASTER BAGHOUSE AT ASARCO-TACOMA

Sample run	Arsenic measurements ^a						
	Inlet			Outlet			
	°C (°F)	mg/Nm ³ (gr/dscf)	kg/hr (lb/hr)	°C (°F)	mg/Nm ³ (gr/dscf)	kg/hr (lb/hr)	Efficiency, percent
1	94 (201)	314.3 (0.138)	92.7 (204)	88 (191)	0.6 (0.0003)	0.2 (0.4)	99.8
2	85 (185)	295.8 (0.130)	88.1 (194)	87 (189)	0.7 (0.0003)	0.2 (0.4)	99.8
3	95 (203)	254.2 (0.111)	79.5 (175)	82 (180)	1.5 (0.0007)	0.5 (1.0)	99.4
Avg.	91 (197)	288.1 (0.126)	86.8 (191)	86 (187)	0.9 (0.0004)	0.3 (0.6)	99.7

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

include six Godfrey roasters, arsenic kitchens, and a metallic arsenic plant. The baghouse, which has been replaced with a new baghouse, consisted of five compartments, each having 288 homopolymer acrylic bags. The bags measured 320 cm (126 in.) in length and approximately 13 cm (5 in.) in diameter. The total filtering area was $1,860 \text{ m}^2$ ($20,000 \text{ ft}^2$). It was designed to effectively treat $850 \text{ Nm}^3/\text{min}$ ($30,000 \text{ scfm}$) at an air-to-cloth ratio of $0.63 \text{ m}^3/\text{min per m}^2$ (2.06 cfm/ft^2). Bag cleaning was performed by mechanical shakers. The outlet sampling was done approximately 150 m (500 ft) downstream of the baghouse. The test results obtained are summarized in Table 3-6.³³

As indicated, the average arsenic inlet concentrations and corresponding mass rate at the baghouse were $2,941 \text{ mg/Nm}^3$ (1.28 gr/dscf) and 76.3 kg/hr (168 lb/hr), respectively. The outlet arsenic loading was 60.6 mg/Nm^3 (0.026 gr/dscf), and the mass rate was 3.3 kg/hr (7 lb/hr). The average arsenic removal efficiency for this unit as indicated by these results was 95.7 percent.

3.2.1.1.2 Spray chamber/baghouse (Anaconda). Inlet and outlet measurements were made at the spray chamber/baghouse separately for arsenic and total particulate emissions. The sampling locations included the two inlet plenums to the spray chamber and the baghouse exhaust duct. Three samples each for arsenic and particulate were obtained at the inlet and outlet. The results of the arsenic emission measurements and particulate emission measurements are summarized in Tables 3-7 and 3-8, respectively.³⁴

When the tests were conducted, the smelter had the following process emission control configuration. Smelting facilities at the Anaconda smelter consisted of a fluid-bed roaster, a single electric furnace, and six converters. Except for a portion of the electric furnace and converter offgases [about $2,070 \text{ Nm}^3/\text{min}$ ($73,000 \text{ scfm}$)], which were diverted to an acid plant for SO_2 removal, process gases from all three major smelting operations were combined into a main flue duct and transported to a baghouse system for particulate removal prior to being discharged to the atmosphere through the main stack.

Table 3-6. ARSENIC PERFORMANCE DATA FOR THE ARSENIC PLANT BAGHOUSE AT ASARCO-TACOMA

Sample run	Arsenic Emissions ^a							
	Inlet				Outlet			
	Arsenic kitchen		Metallic arsenic		Total			
	°C	mg/Nm ³	kg/hr	°C	mg/Nm ³	kg/hr	°C	mg/Nm ³
1	56	1,717	42.4	117	1,931	42.6	83	69.8
2 ^b	58	1,518	42.8	112	1	0.04	72	15.8
3	60	1,532	45.1	97	2,125	55.9	71	96.1
Avg.	58	1,589	43.4	109	1,352	32.9	76	60.6
								3.3

3-52

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

^bDuring this sample run the metallic arsenic process may not have been operating.

Efficiency,
percent

kg/hr

mg/Nm³

°C

Total

Inlet

Arsenic kitchen

mg/Nm³

kg/hr

mg/Nm³

kg/hr

mg/Nm³

kg/hr

mg/Nm³

kg/hr

Efficiency,
percent

Table 3-7. ARSENIC PERFORMANCE DATA FOR SPRAY CHAMBER/BAGHOUSE
AT THE ANACONDA-ANACONDA SMELTER

	Arsenic Emissions ^a						
Sample run	Inlet			Outlet			Efficiency, percent
	°C	mg/Nm ³	kg/hr	°C	mg/Nm ³	kg/hr	
1	274	1,071	276.7	99	7.1	1.8	99.3
2	269	895	236.8	102	9.8	2.5	98.9
3	244	687	186.1	101	12.6	3.4	98.2
Avg.	263	885	232.3	101	9.8	2.6	98.9

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

Table 3-8. PARTICULATE PERFORMANCE DATA FOR SPRAY CHAMBER/BAGHOUSE
AT THE ANACONDA-ANACONDA SMELTER

Sample run	Particulate Emissions ^b						Efficiency, percent
	Inlet			Outlet			
	°C	g/Nm ³	kg/hr	°C	g/Nm ³	kg/hr	
1	281	14.76	4,071	103	0.05	14.6	99.6
2	288	13.57	3,736	103	0.04	10.0	99.7
3	302	14.08	3,860	101	0.05	14.7	99.6
Avg.	290	14.14	3,890	102	0.05	13.1	99.7

^bConcentration and mass rate data are based on measurements on the probe, cyclone, and filter catch (front half).

The baghouse system consists of a baghouse preceded by two parallel spray chambers, which effectively reduce the temperature of the inlet gas stream from about 315°C (600°F) to less than 104°C (220°F) prior to entering the baghouse. The baghouse consists of 18 compartments, each equipped with 240 Orlon bags, and has a net collection area of 29,800 m² (32,080 ft²). It is designed to effectively treat 5,660 Nm³/min (200,000 scfm) at an air-to-cloth ratio of 0.25 m³/min per m² (0.80 cfm/ft²). Bag cleaning is performed by mechanical shakers.

As indicated in Table 3-9, the arsenic inlet concentration and corresponding mass rate were extremely high, averaging 885 mg/Nm³ (0.3867 gr/dscf) and 226.5 kg/hr (498.3 lb/hr), respectively. The outlet arsenic loading was 9.8 mg/Nm³ (0.0043 gr/dscf), and the mass rate was 2.6 kg/hr (5.8 lb/hr). The average arsenic removal efficiency for this unit, as indicated by these results, was 98.9 percent.

Corresponding data in Table 3-10 indicate that the inlet particulate concentration and mass rate averaged 14.14 g/Nm³ (6.2 gr/dscf) and 3,890 kg/hr (8,558 lb/hr), respectively. The outlet particulate loading was 50 mg/Nm³ (0.022 gr/dscf), and the mass rate was 13.1 kg/hr (28.9 lb/hr). The average particulate removal efficiency for this unit was 99.7 percent.

3.2.1.2 Electrostatic Precipitators. Arsenic emission measurements were conducted on the electrostatic precipitator (ESP) units at the ASARCO-Tacoma and ASARCO-El Paso smelters to evaluate the performance of ESP's operated at reduced temperatures. In addition, the ASARCO-El Paso ESP was also tested for particulate matter.

3.2.1.2.1 Electrostatic precipitator (ASARCO-Tacoma). Arsenic emission measurements were conducted by EPA on the outlet of the ESP which treats offgases from the reverberatory furnace. Prior to entering the precipitator, the gases pass through a pair of waste heat boilers where the temperature of the gases is reduced to 400°C (750°F). The exiting gases then pass through a large rectangular brick flue where additional cooling and gas stream conditioning are provided by air infiltration and water and sulfuric acid sprays located in the flue. The resultant gas stream, about 6,100 actual m³/min (215,000 acfm) at 132°C (270°F), then enters the first of two electrostatic precipitators in series for particulate removal. The first precipitator is a tube

or pipe design consisting of 18 sections with a total collection area of about $6,619 \text{ m}^2$ ($71,250 \text{ ft}^2$). Each section contains 84 pipes measuring 30 cm (12 inches) in diameter and 4.6 m (15 feet) in length. The second unit is of a plate-type design, consisting of seven parallel chambers each with four fields in series and with a total collection area of $7,710 \text{ m}^2$ ($82,992 \text{ ft}^2$). The exiting gases, about 7,740 actual m^3/min (270,000 acfm) at 90°C (200°F), are discharged through a large flue to the smelter main stack.

Since the configuration of the inlet duct was such that it was not possible to sample, only outlet arsenic emission measurements were made by EPA at the electrostatic precipitator. The outlet sampling was performed in the duct 23 m (75 ft) downstream of the main stack. Three sample runs were made. A summary of the results obtained at the outlet is presented in Table 3-9.³⁵

Table 3-9. ARSENIC EMISSIONS AT OUTLET OF REVERBERATORY FURNACE ELECTROSTATIC PRECIPITATOR AT ASARCO-TACOMA

Sample run	$^\circ\text{C}$ ($^\circ\text{F}$)	Arsenic Emissions ^a	
		mg/Nm^3 (gr/dscf)	kg/hr (lb/hr)
1	105 (220)	38.1 (0.016)	28.7 (63.1)
2	101 (214)	21.0 (0.009)	11.7 (25.8)
3	87 (188)	9.6 (0.004)	7.1 (15.6)
Avg.	97 (207)	22.9 (0.010)	17.3 (38.2)

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

As indicated, the average arsenic concentration and mass rate at the outlet were $22.9 \text{ mg}/\text{Nm}^3$ (0.01 gr/dscf) and 17.3 kg/hr (38.2 lb/hr), respectively.

3.2.1.2.2 Spray Chamber/Electrostatic precipitator (ASARCO-El Paso).

Inlet and outlet arsenic emission measurements were made by EPA across this spray chamber/ESP. Three runs were made at each of three inlet

locations and at one outlet location. A summary of the test results is presented in Table 3-10.³⁷ Measurements were also made for total particulate emissions on two separate occasions. Three inlet locations and one outlet location were sampled. During the first test, two runs were made at each location. During the later test, three runs were made only at the outlet. Tables 3-11 and 3-12 present the test data.^{36,37}

Smelting facilities at the ASARCO-El Paso smelter consist of four multi-hearth roasters, a single reverberatory furnace, and three converters. When the tests were conducted, the smelter had the following process emission control configuration. Process gases from the reverberatory furnace passed through two parallel waste heat boilers where they were cooled to a temperature of about 400°C (750°F). The existing gas stream was then combined with the roaster offgases in a large rectangular flue. The combined gas stream, which averaged about 5,100 Nm³/min (180,000 scfm), then entered a spray chamber where it was cooled from about 220°C (428°F) to less than 115°C (240°F). After cooling, the combined roaster and reverberatory gases entered an electrostatic precipitator for particulate removal prior to being discharged into the main stack.* The precipitator consists of seven parallel chambers, each containing four sections, with a total electric field volume of 516 m³ (18,228 ft³).

As indicated in Table 3-10, the average arsenic concentration recorded at the inlet and outlet was 0.308 and 0.006 g/Nm³ (0.13 and 0.0026 gr/dscf), respectively. The average mass rates were 95.9 kg/hr (211 lb/hr) at the inlet and 2.1 kg/hr (4.6 lb/hr) at the outlet. The results indicate that the average arsenic removal efficiency of this unit was 97.8 percent for the three runs conducted.

Table 3-11 presents the particulate matter test results obtained during the first test series conducted on the spray chamber/ESP at ASARCO-El Paso. The average particulate concentration and mass rate recorded at the inlet were 5.11 g/Nm³ (2.23 gr/dscf) and 1,134 kg/hr (2,495 lb/hr), respectively. The average particulate concentration and mass rate at the outlet were, respectively, 0.098 g/Nm³ (0.043 gr/dscf)

*In current practice, reverberatory furnace gases are treated separately in one ESP while roaster gases are treated in another ESP.

Table 3-10. ARSENIC PERFORMANCE DATA FOR SPRAY CHAMBER/
ELECTROSTATIC PRECIPITATOR AT ASARCO-EL PASO

Sample run	Arsenic emissions ^a						
	Inlet			Outlet			
	Nm ³ /min	°C	g/Nm ³	kg/hr	Nm ³ /min	°C	g/Nm ³ kg/hr
1	5636	194	0.100	33.8	4054	102	0.005 1.5
2	5983	191	0.338	123.1	4233	104	0.009 3.4
3	3467	252	0.594	123.8	4490	105	0.004 1.5
Avg.	5028	212	0.308	95.9	4259	104	0.006 2.1

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

Table 3-11. PARTICULATE PERFORMANCE DATA FOR THE SPRAY CHAMBER/
ELECTROSTATIC PRECIPITATOR AT ASARCO-EL PASO

Sample run	Particulate Emissions ^a							Efficiency, percent	
	Inlet				Outlet				
	°C	Nm ³ /min	g/Nm ³	kg/hr	°C	Nm ³ /min	g/Nm ³		kg/hr
1	226	3,741	4.54	1,022	105	4,346	0.111	40.8	96.1
2	231	3,631	4.87	1,248	105	4,700	0.085	33.8	97.3
Avg.	229	3,686	5.11	1,134	105	4,523	0.098	37.2	96.7

^aConcentration and mass rate data are based on measurements on the probe, cyclone, and filter catch (front half).

Table 3-12. PARTICULATE PERFORMANCE DATA FOR THE SPRAY
CHAMBER/ELECTROSTATIC PRECIPITATOR OUTLET AT ASARCO-EL PASO

Particulate Emissions ^a				
Sample run	Nm ³ /min	°C	g/Nm ³	kg/hr
1	4,346	104	0.14	47.3
2	4,940	96	0.21	73.0
3	4,816	104	0.09	32.3
Avg.	4,700	101	0.15	50.9

^aConcentration and mass rate data are based on measurements on the probe, cyclone, and filter catch (front half).

and 37.2 kg/hr (81.8 lb/hr). The average particulate removal efficiency measured for the two sample runs performed was 96.7 percent.

Table 3-12 presents particulate matter test results obtained at the outlet of the spray chamber/ESP during the second test series. The average outlet particulate concentration and mass rate values recorded during these latter tests were 0.15 g/Nm^3 (0.066 gr/scf) and 50.9 kg/hr (112 lb/hr), respectively; this is about one and one-half times higher than the values recorded during the earlier tests. The higher concentrations and mass rates recorded in the latter tests were likely due to the higher smelter production rates during those tests.

3.2.1.3 Venturi Scrubbers (Kennecott-Hayden). Arsenic emission measurements were conducted by EPA at the Kennecott-Hayden smelter to evaluate the performance of the venturi scrubber used in series with a spray chamber equipped with impingement plates to preclean and condition fluid-bed roaster offgases prior to acid manufacturing. The roaster process gases pass through a series of primary and secondary cyclones where an estimated 95 percent of the entrained calcine is recovered and the gas stream is cooled to about 315°C (600°F). The cyclone exhaust, consisting of about $565 \text{ Nm}^3/\text{min}$ (20,000 scfm) with an estimated dust loading of 57 g/Nm^3 (25 gr/scf), then enters the venturi scrubber where most of the particulate matter is collected. Weak acid scrubbing liquor is injected into the venturi throat at a rate of about 1,457 liter/min (385 gpm), resulting in a pressure drop of about 41 cm (16 in.) of water across the throat. Gases exiting the scrubber then enter a spray-type scrubber equipped with perforated plates, where they are humidified and cooled to about 46°C (115°F) prior to being combined with the converter process gases, and subsequently treated in a double-contact acid plant. The pressure drop across both scrubbers is about 61 cm (24 in.) of water.

Both inlet and outlet arsenic emission samples were obtained. The inlet sample was collected upstream of the venturi scrubber while the outlet sample was collected downstream of the spray-type scrubber. It was not possible to sample directly downstream of the venturi scrubber because of the system configuration. Table 3-13 presents a summary of the results.³⁸

Table 3-13. ARSENIC PERFORMANCE DATA FOR VENTURI SCRUBBER
AT KENNECOTT-HAYDEN

	Arsenic emissions ^a						
Sample run	Inlet			Outlet			Efficiency, percent
	°C	mg/Nm ³	kg/hr	°C	mg/Nm ³	kg/hr	
1	336	29.53	0.85	46	0.64	0.02	97.9
2	328	25.87	0.74	44	0.27	0.01	98.9
3	324	22.90	0.75	28	0.32	0.01	98.8
Avg.	329	26.10	0.78	39	0.41	0.01	98.4

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

As the results indicate, the arsenic inlet loading to the scrubber was quite low, averaging 26.10 mg/Nm³ (0.0114 gr/dscf) and 0.78 kg/hr (1.72 lb/hr). The outlet concentration was very low, averaging 0.41 mg/Nm³ (0.0002 gr/dscf). The arsenic mass emission rate at the outlet averaged 0.01 kg/hr (0.023 lb/hr). The average collection efficiency observed was 98.4 percent. It should be noted that the three inlet runs exceeded isokinetic tolerances (refer to Appendix C). This was due primarily to the large fluctuations in the moisture content of the gas stream from run to run. As a result, the actual inlet concentration was probably somewhat higher than that measured. Consequently, the actual arsenic collection efficiency of the system is probably slightly higher than the 98.4 percent recorded.

3.2.1.4 Sulfuric Acid Plants. Tests were performed at the Kennecott-Hayden, ASARCO-El Paso, and Phelps Dodge-Ajo smelters to evaluate the performance of acid plants in controlling arsenic emissions.

Gas precleaning and conditioning of the smelter offgases used for sulfuric acid manufacturing is absolutely necessary for effective acid plant operation. Both hot and cold gas cleaning devices are used.

3.2.1.4.1 Double-contact acid plant (Kennecott-Hayden). The double-contact acid plant operated at this smelter treats a combination of fluid-bed roaster and converter process gases. Acid production is typically about 935 Mg/day (850 tpd) of 93.5 percent sulfuric acid.

After passing through a series of cyclones for calcine recovery, the fluid-bed roaster offgases are treated in a venturi scrubber for particulate removal and a spray tower for humidification and cooling. The converter offgases are captured in water-cooled hoods, cooled to 370°C (700°F) in a gas cooler, and routed to an electrostatic precipitator for particulate removal. Gases exiting the precipitator enter a spray tower, similar to that used on the roaster gas stream, where they are humidified, cooled, and subsequently combined with the roaster gas stream. The combined gas stream, totaling about 2,120 Nm³/min (75,000 scfm) at 46°C (115°F), then passes through three parallel trains of two mist precipitators in series, where acid mist and any remaining particulates are precipitated. The gas stream, which typically contains 5 to 8 percent SO₂, then enters the double-contact acid plant where it is dried, the SO₂ converted to SO₃, and the SO₃ absorbed in weak acid to form strong acid.

Three arsenic test runs were conducted by EPA on the acid plant tail gas stream (outlet). These tests were performed concurrently with those across the venturi scrubber described in the preceding section. The average arsenic concentration measured was 3.43 mg/Nm³ (0.0015 gr/dscf). The corresponding arsenic mass rate averaged 0.41 kg/hr (0.90 lb/hr).³⁸

3.2.1.4.2 Double-contact acid plant (ASARCO-El Paso). Offgases generated during converter blowing operations at the ASARCO-El Paso smelter are treated in a 454 Mg/day (500 tpd) double-contact sulfuric acid plant for SO₂ removal. The offgases are captured in water-cooled hoods, passed through two parallel waste heat boilers, and cooled by evaporative cooling in a spray chamber. The cooled gases [about 1,700 Nm³/min (60,000 scfm) at 149°C (300°F)] then enter an ESP for particulate removal. The precipitator consists of four parallel chambers, each having four sections in series. The exiting gases pass through a venturi scrubber for additional particulate removal, are humidified and cooled in a pair of packed bed scrubbers, and then are treated in a series of mist precipitators where water and any remaining particulates are removed prior to entering the acid plant.

Arsenic emission measurements were conducted by EPA at the inlet to the spray chamber and at the acid plant outlet. Three sample runs were made on the inlet and four on the outlet. The results are summarized in Table 3-14.³⁹

Table 3-14. ARSENIC PERFORMANCE DATA FOR DOUBLE-CONTACT ACID PLANT AT ASARCO-EL PASO

	Arsenic emissions ^a						
Sample run	Inlet			Outlet			Efficiency, percent
	°C	g/Nm ³	kg/hr	°C	g/Nm ³	kg/hr	
1	222	2.36	233.3	64	0.0002	0.022	99.99
2	209	0.228	21.4	64	0.0031	0.355	98.3
3	200	0.262	24.4	66	0.0011	0.126	99.5
4	b	b	b	69	0.0004	0.038	b
Avg.	210	0.976	96.0	67	0.0015 ^c	0.168 ^c	99.8

^a

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

^bOnly three inlet sample runs were made.

^cAverage of first three runs only.

As indicated, the measured inlet and outlet arsenic concentrations averaged 0.976 g/Nm³ (0.426 gr/dscf) and 0.0015 g/Nm³ (0.0007 gr/dscf), respectively. The arsenic mass rate averaged 96.0 kg/hr (211 lb/hr) at the inlet and 0.168 kg/hr (0.370 lb/hr) at the outlet, indicating an average arsenic removal efficiency in excess of 99 percent.

3.2.1.4.3 Single-contact acid plant (Phelps Dodge-Ajo). Offgases generated during converting at the Phelps Dodge-Ajo smelter are treated in an ESP system for particulate removal followed by a 544 Mg/day (600 tpd) single-contact sulfuric acid plant for SO₂ removal. The offgases pass through waste heat boilers where they are cooled to about 315°C (600°F), enter a balloon flue, and then pass through an electrostatic precipitator. The precipitator consists of two independent horizontal parallel units with three fields, each of which is designed to handle 5,490 m³/min (210,000 acfm) at 340°C (650°F) and 95.1 kPa

(13.8 psia). The exiting gases pass into the scrubbing section of the acid plant where they are treated in a humidifying tower, a cooling tower, and a mist precipitator. The cleaned gases are then processed in the acid plant. Either 93 or 98 percent sulfuric acid can be produced.

Simultaneous inlet and outlet arsenic emission measurements were conducted by EPA. Three sample runs each were made on the inlet and outlet. The results are summarized in Table 3-15.⁴⁰ The offgases treated in the acid plant contained a negligible amount of arsenic. The measured inlet and outlet concentrations averaged 0.00007 g/Nm³ (0.00003 gr/dscf) and 0.000016 g/Nm³ (0.000007 gr/dscf), respectively. The arsenic mass rate averaged 0.004 kg/hr (0.009 lb/hr) at the inlet and 0.001 kg/hr (0.0022 lb/hr) at the outlet, indicating an average arsenic removal efficiency of 75 percent.

Table 3-15. ARSENIC PERFORMANCE DATA FOR SINGLE-CONTACT ACID PLANT AT PHELPS DODGE-AJO

	Arsenic emissions ^a						
Sample run	Inlet			Outlet			Efficiency, percent
	°C	g/Nm ³	kg/hr	°C	g/Nm ³	kg/hr	
1	190	0.00008	0.006	60	0.000007	0.0006	90.0
2	182	0.00003	0.002	73	0.00001	0.0007	65.0
3	172	0.00009	0.005	53	0.00003	0.0013	64.0
Avg.	181	0.00007	0.004	62	0.000016	0.001	75.0

^aConcentration and mass rate data are based on measurements on the total catch (front and back half).

3.2.2 Fugitive Control Systems Evaluation

3.2.2.1 Local Ventilation Techniques Applied to Calcine Discharge,

Matte Tapping, and Slag Tapping.

The performance capability of the local ventilation techniques used at the ASARCO-Tacoma smelter for the control of fugitive arsenic emissions from calcine discharge, matte tapping, and slag tapping operations were evaluated. These techniques were previously described in Sections 3.1.2.4, 3.1.2.5, and

3.1.2.6, respectively. Visual observations were made using either EPA Method 22 or EPA Method 9, depending on whether the emissions observed were intermittent or continuous. Method 22 is used to determine the occurrence of visible emissions, while Method 9 is used to determine the opacity of emissions. A summary of the visible emission data obtained is presented in Table 3-16.⁴¹

3.2.2.1.1 Calcine transfer. Thirteen calcine transfer operations, each averaging about 2 minutes in duration, were observed. The visual observations were made using EPA Method 22 at the opening of the tunnel-like structure used to house the calcine hoppers and larry cars during the calcine transfer (discharge) operations. As the data indicate, no visible emissions were observed at any time.

3.2.2.1.2 Matte tapping. Visible emission observations during furnace matte tapping were also made using EPA Method 22. Simultaneous but separate observations were made both at the furnace tap port and at the launder-to-ladle transfer point. Sixteen taps, averaging approximately 5.5 minutes in duration, were observed at the tap port. Out of the 16 observations made at the matte tap port, no visible emissions were observed 100 percent of the time on 14 of these, with only slight emissions ranging from 1 to 3 percent of the time for the remaining two observations. No visible emissions were observed 100 percent of the time from the launder-to-matte ladle transfer point during all 15 observations made at the transfer point.

3.2.2.1.3 Slag tapping. Slag tapping emissions were observed using both EPA Methods 22 and 9. As with matte tapping, separate observations were made at the furnace tap port location and at the slag launder-to-slag pot transfer point. Results obtained using EPA Method 22 for eight observations at the slag tap port showed that visible emissions were observed about 5 percent of the time on the average, with the highest single observation showing the presence of visible emissions 15 percent of the time. Visual observations made at the slag launder-to-pot transfer point indicated very poor performance, with visible emissions being observed 72 to 99 percent of the time over 11 slag taps. Additional data obtained using EPA Method 9 showed significant emissions with opacities as high as 50 percent. Conversations

Table 3-16. SUMMARY OF VISIBLE EMISSION OBSERVATION DATA FOR CAPTURE
SYSTEMS ON FUGITIVE EMISSION SOURCES AT ASARCO-TACOMA^a

Operation	EPA Method 22				EPA Method 9			
	No. of readings taken	Average observation time, min:sec	Average percent emissions observed on all readings	Range of percent time emissions observed	No. of readings taken	Average observation time, min:sec	Average opacity, percent	Range of opacity, percent observed
Calcine transfer system	13	1:55	0	0				
Matte tapping: at matte tap port and launder	16	5:28	0.2	0-3				
at matte discharge into ladle	15	5:21	0	0				
Slag tapping: at slag tap port and launder	8	13:38	5.3	0-15	2	13:45	6	0-30
at slag discharge into pots	11	15:27	88	72-99	7	14:32	12	0-50

^aVisible emission observations made on June 24 through 26, 1980.

with smelter personnel revealed that the ventilation hood at the slag launder discharge point had been damaged when hit by a truck. Although an inspection of the ventilation hood and ancillary ductwork showed no apparent damage, ventilation at this location was concluded to be inadequate to handle the volume of emissions and fume generated.

3.2.2.2 Fugitive Emission Controls for Converters-Air Curtain Secondary Hood Capture System.

3.2.2.2.1 Evaluation program at ASARCO-Tacoma. EPA conducted an evaluation program in January 1983, on the prototype air curtain secondary hood recently installed at ASARCO-Tacoma.²⁹ The primary objective of this test program was to obtain an estimate of the overall capture efficiency of the air curtain control system and also the capture efficiency during specific modes of converter operation. Capture efficiencies of the system during three complete converter cycles were estimated using two principal techniques: (1) a gas tracer study using sulfur hexafluoride (SF_6) was performed by injecting the gas into the fugitive emission plume and measuring the amount of the gas captured by the secondary hooding system, and (2) detailed visual observations of the hooding system performance were made concurrent with the gas tracer study.

In the gas tracer study, SF_6 was injected into the controlled area of the air curtain at constant, known rates of 30 to 50 cc/min for periods which ranged from 15 minutes to 2 hours per injection. Single point samples of the exhaust gases from the air curtain hood were collected at a downstream sampling location by pulling samples into 15-liter, leak-free Tedlar bags for onsite gas chromatographic analysis. The air curtain capture efficiency was calculated by comparing the SF_6 injection mass flow rate with the mass flow rate calculated for the downstream sampling point.

Injections of SF_6 gas were made at 16 sample points through 4 test ports in adjacent access doors on both sides of the converter baffle walls. The locations of the points are shown in Figures 3-18 and 3-19. In addition to the efficiency measurements made for the points in the primary testing area, several tests were performed at injection points outside of this area (below the converter centerline) in

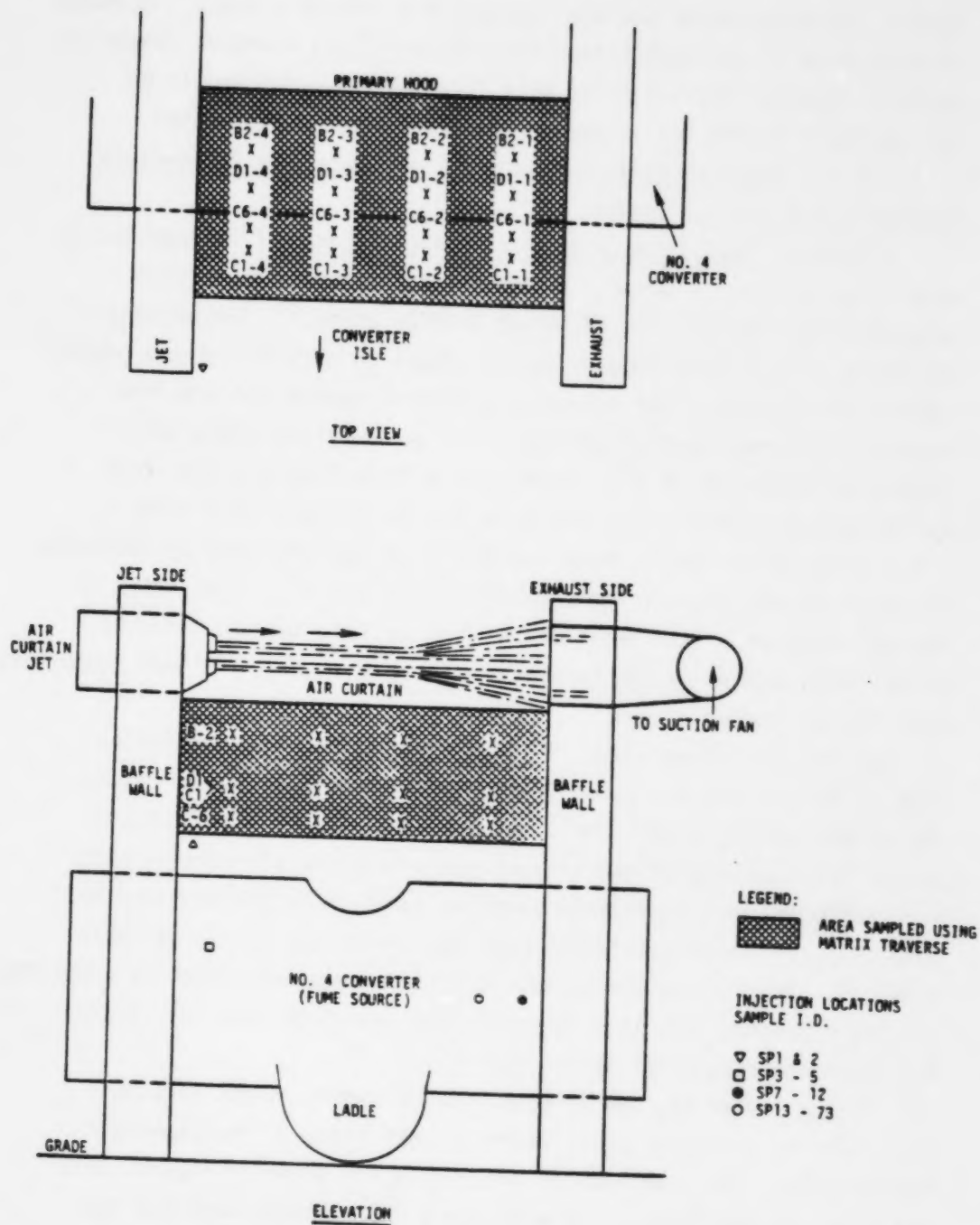


Figure 3-18. SF_6 Tracer Injection Locations

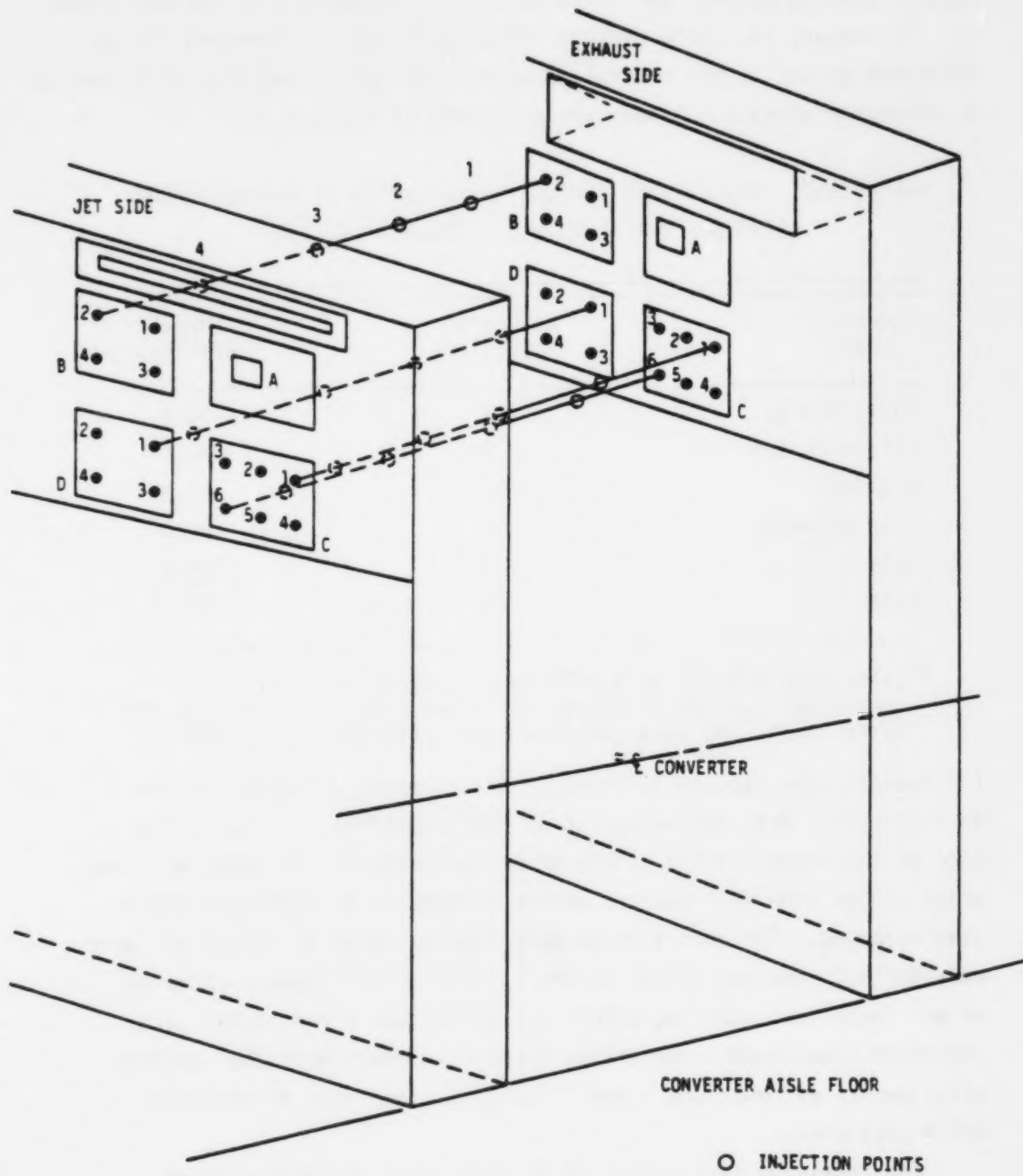


Figure 3-19. Tracer Injection Test Ports

an attempt to characterize the effective capture area of the air curtain hooding system, particularly during converter roll-out activities.

On January 14, 1983, capture efficiencies were determined for 45 injection points in the controlled area. The calculated mean efficiencies by converter operational mode are presented in Table 3-17.

Table 3-17. AIR CURTAIN CAPTURE EFFICIENCIES AT ASARCO-TACOMA
USING GAS TRACER METHOD - JANUARY 14, 1983

Converter mode	Number of injections	Mean efficiency
Matte charge	7	93.1
Cold addition	3	102.0
Blowing	19	92.8
Slag skimming	9	95.0
Idle	<u>7</u>	<u>93.4</u>
TOTAL	45	93.5 ^a

^aCalculated overall mean efficiency assumes the converter operation consists of 80 percent blowing and idle, 15 percent matte charge and cold addition, and 5 percent slag skimming.

The overall mean capture efficiency for all modes of operation was 93.5 percent. With the exception of cold additions, the operating mode of the converter had little effect on capture efficiency measured, which ranged from 92.8 percent during blowing to 95.0 percent during slag skimming. The port through which the releases of tracer gas were made did not have any effect on the calculated efficiency. However, it was found that sampling points tested through a particular port exhibited considerable variation, generally recording higher capture efficiencies at positions 1 and 2 (exhaust side) than at positions 3 and 4 (jet side).

The remaining test series of 48 injections was performed on January 17-18, 1983. The results of this series are summarized in Table 3-18.

Table 3-18. AIR CURTAIN CAPTURE EFFICIENCIES AT
ASARCO-TACOMA USING GAS TRACER METHOD - JANUARY 17-19, 1983

Converter mode	Number of injections	Mean efficiency
Matte charge	6	94.2
Cold addition	3	96.7
Blowing	27	96.7
Slag skimming	7	94.3
Copper pour	4	88.5
Idle	4	100.0
TOTAL	51	96.5 ^a

^aCalculated overall mean efficiency assumes the converter operation consists of 80 percent blowing and idle, 15 percent matte charge and cold addition, and 5 percent slag skimming and copper pour.

The overall mean capture efficiency for all operational modes was 96.5 percent. As with the data recorded on January 14, the operating mode appeared to have no significant effect on the individual calculated efficiencies, which ranged from 88.5 percent during copper pouring to 96.7 percent during both blowing and cold additions. However, any consistent, small variations in the efficiencies for various modes, if they were present, would be difficult to detect in the relatively small number of test runs (injections) which were made. The error in the calculated air curtain capture efficiencies has been estimated to be ± 18 percent.⁴² For this second test series, it was also found that the location of the test port had no effect on efficiency, while exhaust-side efficiencies were found to be somewhat higher than jet-side efficiencies. Test results from the injection points in these tests indicate that, on the average, about 95 percent of the gases and particulate matter in the area immediately above the converter is likely to be captured by the air curtain secondary hooding system.

In addition to these two test series, a series of special injection point tests was conducted in order to assess the effective capture area of the secondary hood system outside the confines of the hood. The special injection tests were performed with the injection probe at a number of points on the perimeter of the main test area, such as very close to the baffle wall and below the ladle during the matte charging and cold addition modes. Table 3-19 shows the results of this test series.

Table 3-19. AIR CURTAIN CAPTURE EFFICIENCIES AT ASARCO-TACOMA
FOR SPECIAL GAS TRACER INJECTION POINTS -
JANUARY 18-20, 1983

Converter mode	Number of injections	Mean efficiency
Matte charge	17	61.8
Cold addition	6	61.5
Blowing	6	33.0
Slag skimming	28	84.0
Copper pour	4	80.8
Idle	8	53.8
TOTAL	69	49.4 ^a

^aCalculated overall mean efficiency assumes the converter operation consists of 80 percent blowing and idle, 15 percent matte charge and cold addition, and 5 percent slag skimming and copper pour.

The overall average capture efficiency for the 69 special injection points was 49.4 percent. Unlike the first two test series, the capture efficiency in the special series was sensitive to converter mode. For example, the slag skimming and copper pour efficiencies are higher, at 84.0 and 80.8 percent, respectively, than the other modes because of the position of the ladle (above the injection probe) during these modes.

During the course of the gas tracer study, from January 18 to 22, 1983, detailed visual observations were made of the performance of the

air curtain control system through the various converter operating modes.⁴³ The purpose was to estimate capture effectiveness and to qualitatively characterize both captured emissions and emissions escaping capture.

An important benefit from these observations which could not be derived from the results of the gas tracer study was the conclusion that operating practices play a major role in the overall performance of the control system. The crane operator who moves the ladle into position for charging, skimming, or pouring has some latitude in the positioning of the ladle, the speed of pouring, and the speed and timing of the movement of the ladle to and from the converter. Observations show that slower, more deliberate movements and closer positioning of poured materials to the converter have a definite effect on the extent of air curtain penetration and spillage into the converter aisle.

The practices employed by crane and converter operators were found to vary significantly throughout the observation period. For example, during slag skimming, it was observed that the rate of pouring varied for individual skims. The capture efficiency was higher when the pour rate was lower, since a faster rate would sometimes "overwhelm" the control system. Also, the position of the ladle was noticed to be important, because when the ladle was positioned close to the converter mouth the capture efficiency was enhanced. During matte charging, the withdrawal of the crane from above the converter was often observed to cause "drag-out" emissions, especially when the crane was moved immediately after the converter was charged. When the crane was left in place for a few moments after charging (and the heaviest part of the emissions had risen to the air curtain), the drag-out emissions were noticeably reduced, and the capture effectiveness was improved.

Only one period of blowing was evaluated quantitatively during the observations. Some penetration of the air curtain was noticed (5 to 10 percent) during roll-in when the blowing air first started, but the overall capture efficiency was judged to be about 95 percent.

Overall capture efficiencies for individual matte chargings were in the range of 90 to 95+ percent. Cold additions (adding of cool,

solidified materials) to the converter frequently produced emissions heavy enough to virtually overwhelm the capture system, especially when a fire ignited in the converter. Capture efficiencies were somewhat lower overall than for matte charging, typically ranging from 80 to 95 percent.

During slag skimming, it was observed that the rate of pouring varied for individual skims. For pour rates judged to be slow or moderate, efficiencies generally ranged from 80 to 95 percent. For faster pour rates, the typical efficiencies dropped to 70 to 80 percent.

Copper pouring generally produced a moderate to heavy amount of fume; both air curtain penetration and spillage out into the converter aisle were very slight. Capture efficiencies were typically 90 to 95 percent during pouring. However, at initial roll-out prior to pouring, the efficiency could be as low as 70 percent.

The observation that fumes would frequently spill out into the converter aisle (especially during slag skimmer activities) indicates that the entire fugitive emission plume either is captured by the air curtain exhaust or penetrates the curtain vertically (since vertically escaping gases should contain a homogeneous concentration of the tracer gas). Therefore, by not accounting for emissions which escape before approaching the air curtain, the gas tracer method probably overpredicted the capture efficiency achieved during slag skimming operations.

In general, visual assessments of secondary hood capture effectiveness correlate quite well with the average efficiencies determined by the gas tracer method. As mentioned earlier, operating practices have a significant influence on the degree of capture achieved during any individual converter operation, and many of the extreme observed values can be understood in terms of the operating practices employed during those particular operations.

3.2.2.2.2 Visible Emissions Observations at Tamano Smelter. All three converters at the Tamano smelter in Japan are equipped with a fixed enclosure and air curtain system for control of fugitive emissions generated during various modes of converter operation. The enclosure doors and roof are kept open and the air curtain system is turned on during the matte charging. During all other modes of the converter operation the doors and roof are kept closed and the air curtain system is turned off. This system is described in Section 3.1.2.7.2.

Visible emission observations were made for the air curtain secondary hood operated on the No. 3 converter during day-shifts on March 12 and March 13, 1980. The converter is a conventional Pierce-Smith design, measuring about 9 meters in length and 4 meters in diameter. Observations were made using EPA Methods 22 and 9, depending on whether the emissions observed were intermittent or continuous, for the different modes of converter operation comprising a converter cycle. A discussion of the results obtained during each mode of converter operation follows.

Matte charging. Usually three ladles of matte are brought to the converter and charged in a 10- to 30-minute period. Actual matte charging from each ladle lasts for 1 to 1.5 minutes. The fixed enclosure doors and roof are opened; the air curtain system is turned on; and the ladle of matte is brought into the secondary hood by an overhead crane. The converter is rolled down to an inclined position; the matte ladle is lifted up by the crane; and matte is charged into the converter. At the completion of matte charge, the ladle is moved out of the enclosure and, if needed, another ladle of matte is brought in. After the matte additions are completed, the converter is rotated into the primary converter hood, the roof and doors are closed, and slag blowing is commenced.

Three separate matte charges were observed using both EPA Methods 9 and 22 simultaneously, and one matte charge was observed using EPA Method 9 only. Visual observations for each matte charge observed were made only during the period when the matte was actually flowing into the converter. Results of the visual observations obtained are summarized in Table 3-20.⁴⁴

As shown in Table 3-20, visible emissions were observed for three individual matte charges. The observations ranged from 44 to 77 percent of the time (EPA Method 22). Although somewhat continuous, the opacity results indicate that these emissions were generally slight, typically ranging from 0 to 10 percent opacity, with the highest average opacity recorded for a single matte charge being 25 percent. When present, the emissions appeared as small puffs which penetrated the air curtain stream.

Table 3-20. VISIBLE EMISSIONS OBSERVATION DATA
FOR CONVERTER SECONDARY HOOD SYSTEM
DURING MATTE CHARGING AT THE TAMANO SMELTER

Sample run	Method 22		Method 9		
	Observation period, min	Percent of time emissions observed	Observation period, min	Average opacity for observation period, percent	Range of individual readings
1	1.5	44	1.5	5.0	0 to 25
2	1.25	56	1.25	4.0	0 to 10
3	1.75	77	1.75	3.0	0 to 10
4	-	-	1.5	0	-
Total	4.50	60	6.25	2.8	0 to 25

Slag blow and copper blow. During slag blowing and copper blowing, the converter mouth is enclosed by the primary duct, and offgases are directed to the acid plant. The converter secondary hood doors and roof are closed, and the air curtain system is turned off. Fugitive emissions generated during blowing as a result of primary hood leaks are captured inside the converter housing and are vented to a baghouse for collection. The slag blow, which is divided into three segments, lasts for about 150 minutes per converter cycle and the copper blow for about 200 minutes per cycle.

Visible emission observations were made using EPA Method 9 for the converter hood system for 30 minutes during the slag blow and for 27 minutes during the copper blow. No visible emissions (zero percent opacity) were observed at any time.⁴⁴

Slag discharge. At the end of each of the three slag blow phases, slag is skimmed into a ladle and transported to a sand bed area for cooling. Because of the quantities involved, slag is discharged from the converter two times after the first slag blow and once after the second and third. Each slag skim lasts for about 10 minutes. During each skim, an empty ladle is brought into the enclosure by an overhead crane and placed on the ground in front of the converter. The crane is moved out, and the enclosure doors and roof are closed. The converter is rolled down, and slag is poured into the ladle. After the slag skimming is completed, the converter is rotated upward slightly, the enclosure doors are opened, and the slag ladle is moved out.

Only two skims were observed. The first, which lasted 11 minutes, was observed using EPA Methods 22 and 9. The second slag skim, lasting 9 minutes, was observed using EPA Method 22 only. Each observation period began as the converter started rolling down to pour the slag into the ladle and lasted until the pouring was completed and the converter started rolling up. During the first slag skim observed, no visible emissions were observed at any time. In contrast, during the second slag skim, visible emissions were observed 100 percent of the time. Most of the time, however, these emissions were slight, ranging from 5 and 10 percent opacity and consisting of small puffs which escaped from the enclosure through a narrow opening between the front doors and the enclosure roof.⁴⁴

Blister discharge. At the end of copper blowing, the product blister is discharged into a ladle and transported to a refining furnace. Usually four ladles of blister are filled per converter cycle. Each of the first three blister pours lasts about 12 to 14 minutes with the final pour lasting about 4 minutes. The time elapsed between each blister pour is about 8 to 15 minutes.

At the end of a copper blow, the secondary hood doors and roof are opened. An empty ladle is brought into the secondary hood by the overhead crane and placed in front of the converter. The crane is moved out, and the secondary hood doors and roof are closed. The converter is rolled down, and blister is poured into the ladle. After the blister pour is completed, the converter is rolled up slightly;

the hood doors are opened; the blister ladle is taken to the refining furnace by the crane; and the hood doors and roof are closed.

Four blister discharges were observed. Both EPA Methods 22 and 9 were used. A summary of the results is presented in Table 3-21.⁴⁴ Although the observation periods used in obtaining the EPA Method 22 data were variable (i.e., different start and end times), the results nonetheless indicate that visible emissions during blister discharge were generally continuous. The EPA Method 9 data, which were obtained only during periods when the blister copper was actually being poured, show that the visible emissions observed were somewhat more substantial than those observed during either matte charging or slag skimming. As shown in Table 3-21, the highest average opacity recorded for a single blister pour was 13 percent, with individual opacity readings ranging from 0 to 35 percent. Again, as with slag skimming, the emissions observed generally appeared above the narrow opening between the front doors of the enclosure and the enclosure roof.

Table 3-21. VISIBLE EMISSIONS OBSERVATION DATA FOR BLISTER DISCHARGE AT THE TAMANO SMELTER

Sample Run	Method 22		Method 9		
	Observation period, min.	Percent of time emissions observed	Observation period, min	Avg. opacity for observation period, percent	Range of individual opacity readings
1	25 ^a	42	-	-	-
2	-	-	15.0	6.2	0 to 30
3	15 ^b	86	12.0	13.0	0 to 35
4	6 ^c	19	3.5	3.2	0 to 25
Total	15.3	49	30.5	8.5	0 to 35

^aObservations started when secondary hood doors opened 12 minutes prior to the blister discharge, during which time the converter body was hit by a vibrating ram.

^bObservations started with the blister discharge and continued for 3 minutes after completion of the blister discharge.

^cObservations started with the blister discharge and continued for 2-1/2 minutes after completion of the blister discharge.

3.2.2.3 Building Evacuation and Baghouse (ASARCO-El Paso) - Fugitive emissions from converters and anode furnaces at the ASARCO-El Paso smelter are captured by evacuating the converter building. The building evacuation system at this smelter is described in Section 3.1.2.7.3. The captured fugitive gases are drawn through four openings at the roof of the converter building into ducts which merge into a main duct leading to a baghouse, then through fans to the 250 m (828 ft) main stack.

The fugitive gas flow through the baghouse averages about 14,100 Nm³/min (498,000 scfm). The baghouse consists of 12 compartments. Normally all compartments are in operation except that one compartment is taken off during the cleaning cycle and another compartment during the maintenance cycle. Each compartment contains 384 Orlon or Dacron bags, 20 cm (8 in.) in diameter and 6.7 m (22 ft) long, providing a cloth area of 1,644 m² (17,700 ft²) per compartment. The total net cloth area of the baghouse is about 19,732 m² (212,400 ft²). The baghouse was designed to effectively treat 15,280 m³/min (540,000 acfm) at 54°C (130°F) with an air-to-cloth ratio of 0.91 m³/min per m² (3 cfm/ft²). Mechanical shakers are used for cleaning the bags.

Inlet and outlet emission measurements for inorganic arsenic and total particulate were conducted by EPA across the baghouse. During all tests, converter operations were monitored and testing was conducted only when one or more converters were in operation. The arsenic results obtained are summarized in Table 3-22.⁴⁵ As indicated, the measured inlet and outlet arsenic concentrations averaged 3.27 mg/Nm³ (0.0014 gr/scf) and 0.137 mg/Nm³ (0.00006 gr/scf), respectively. The arsenic mass rate averaged 2.92 kg/hr (6.45 lb/hr) at the inlet and 0.111 kg/hr (0.244 lb/hr) at the outlet, indicating an average arsenic removal efficiency in excess of 96 percent. The results of the particulate measurements obtained are summarized in Table 3-23.⁴⁶ As shown in the table, the mass particulate inlet concentration was low, averaging only 0.062 g/Nm³ (0.027 gr/scf). Nonetheless, the mass particulate emission rate was relatively high, averaging over 50 kg/hr (110 lb/hr). The low inlet concentration is a result of the large quantities of dilution air associated with the application of general ventilation

Table 3-22. ARSENIC DATA FOR CONVERTER BUILDING
BAGHOUSE AT ASARCO-EL PASO

Arsenic emissions							
Sample run	Inlet			Outlet			Efficiency, percent
	°C	mg/Nm ³	kg/hr	°C	mg/Nm ³	kg/hr	
1	38	6.21	5.51	38	0.39	0.305	94.5
2	36	2.09	1.96	37	0.017	0.017	
3	51	1.53	1.31	51	0.015	0.012	99.1
Avg.	42	3.27	2.92	42	0.137	0.111	99.1
							96.2

Table 3-23. PARTICULATE DATA FOR CONVERTER BUILDING
BAGHOUSE AT ASARCO-EL PASO

TABLE 11-13

Sample run	Particulate emissions						Efficiency, percent
	Inlet			Outlet			
	°C	mg/Nm ³	kg/hr	°C	mg/Nm ³	kg/hr	
1	16	60.3	44.7	20	11.6	10.4	76.7
2	22	53.3	46.3	14	2.5	0.92	
3	16	70.5	61.2	16	1.1	6.4	99.3
Avg.	18	61.3	50.7	17	5.1	3.9	91.3

techniques. The outlet concentration and mass rate averaged 5.1 mg/Nm^3 and 3.9 kg/hr , respectively. Although the collection efficiency obtained over three test runs averaged only about 90 percent, the results indicate that collection efficiencies as high as 99 percent are achievable.

3.2.3 Conclusions

3.2.3.1 Process Controls. As discussed in Section 3.1.1.1, the arsenic control devices considered as best available control for process sources at primary copper smelters incorporate gas stream precooling as an integral part of the overall control system. Cooling is vital to effective control because the relatively low saturation concentration of arsenic trioxide at lower temperatures allows a greater percentage of the arsenic to condense into a form which can be collected in a particulate control device. The process control systems tested and discussed in Section 3.2.1 include the spray chamber/baghouse system at Anaconda; the roaster and arsenic plant baghouses at ASARCO-Tacoma; the spray chamber/ESP at ASARCO-El Paso; the reverberatory furnace ESP at ASARCO-Tacoma; the venturi scrubber at Kennecott-Hayden; and the acid plants at ASARCO-El Paso, Kennecott-Hayden, and Phelps Dodge-Ajo. The inlet temperature to the baghouses and the electrostatic precipitators ranged between 80 and 115°C (180 to 240°F).

The results of these tests, in terms of the arsenic collection efficiencies recorded, are shown in Figure 3-20. (The results of ESP testing at ASARCO-Tacoma are not presented in Figure 3-20, because the data were collected only for the ESP outlet; and the results of the single-contact acid plant at Phelps Dodge-Ajo, are not presented because of its measured 75 percent efficiency due to extremely low inlet arsenic loadings.) Each black circle in the figure represents a sample run performed on the control device designated at the bottom of the figure. The average efficiencies (designated by horizontal bars) ranged from a low of about 96 percent (baghouse at 84°C) to a high of about 99.7 percent (baghouse at 91°C). The data demonstrate that baghouses, ESP's, venturi scrubbers, and acid plants can be used to provide a high level of control for arsenic emissions. However, as discussed earlier, the collection efficiency for arsenic of any particulate

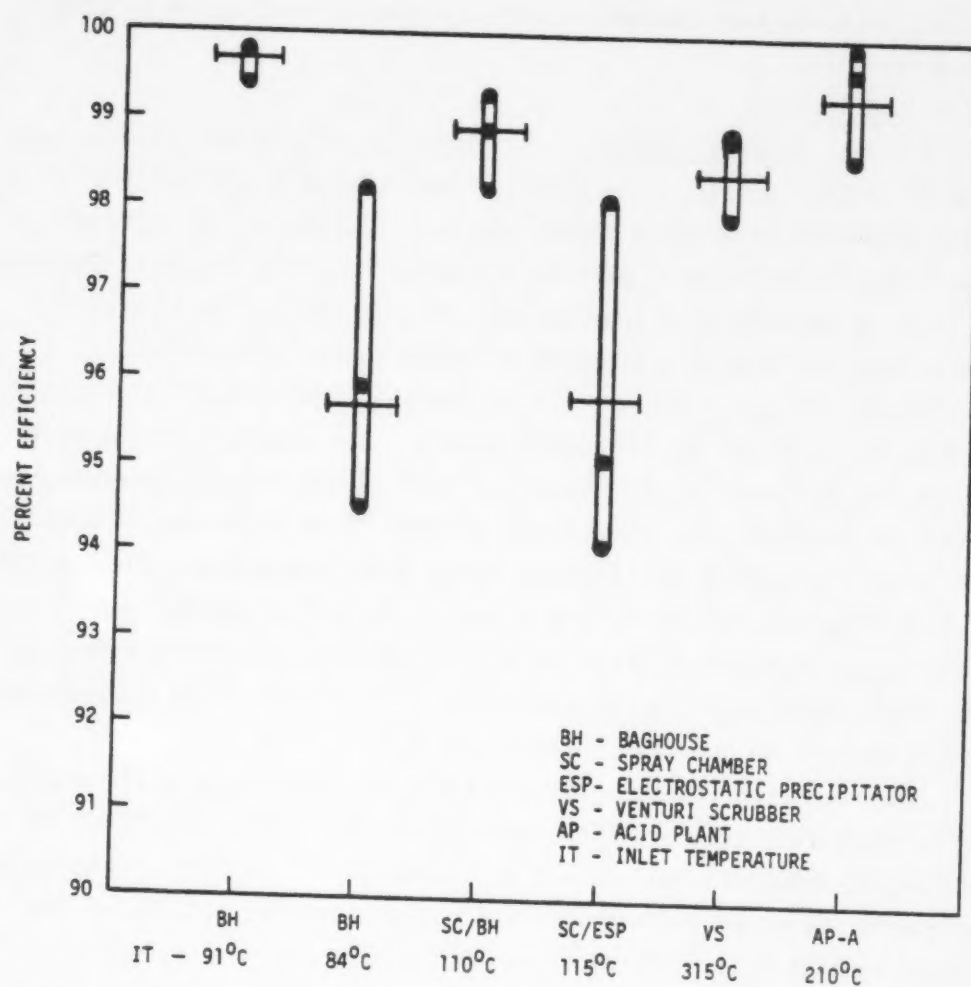


Figure 3-20. Control Device Arsenic Collection Efficiencies

control device can vary depending on the distribution between the particulate and vapor form of the arsenic which reaches the device. This distribution in turn depends on the arsenic concentration in the gas stream and the stream temperature. Therefore, any discussion of control efficiency of a particular type of device must consider these parameters before an estimate of the expected efficiency can be made. The process gas streams entering the control devices tested clearly had sufficiently high concentrations of arsenic trioxide for high control efficiencies to be achieved.

3.2.3.2 Fugitive Controls. The performance capabilities of capture systems for the control of fugitive arsenic emissions from calcine discharge, matte tapping, slag tapping, and converter operations were evaluated. Estimates of the capture efficiency of these systems are based on the visible emissions observations reported in the preceding sections and on subjective judgment. Also evaluated was the performance capability of a baghouse control device used to collect captured fugitive emissions.

Visual observations made on the local ventilation system applied to calcine discharge operations at ASARCO-Tacoma resulted in no visible emissions being observed at any time during the observation period. As a result, it is concluded that such a system is readily capable of achieving a capture efficiency of 90 percent or better.

Observations conducted on the local ventilation system applied to matte tapping operations at the same smelter showed no visible emissions occurring at any time at the matte launder-to-ladle transfer point and only slight emissions of short duration, a maximum of 3 percent of the time, for any individual matte tap observed at the matte tap port. It is concluded, based on these data, that a properly designed and operated ventilation system applied to matte tapping operations should achieve a minimum capture efficiency of 90 percent.

Similar observations made on the ventilation system serving the slag tapping operations at Tacoma showed substantially poorer performance, especially at the slag launder-to-slag pot transfer point where visible emissions were observed nearly 100 percent of the time during each individual slag tap. Based on the results of the visual observations

and the fact that the capture system had reportedly been damaged, it is concluded that the slag tapping ventilation system observed at Tacoma, as it was operating at the time, should not be considered representative of a best system of emission reduction. Although slag tapping operations do represent a somewhat more difficult control situation than matte tapping, the outstanding performance demonstrated by the matte tapping controls at Tacoma strongly suggest that a properly designed and operated ventilation system applied to slag tapping operations should be capable of achieving at least 90 percent capture.

Capture systems evaluated for the control of fugitive arsenic emissions from converter operations included the prototype air curtain secondary hoods applied at the ASARCO-Tacoma smelter and the Mitsui Smelting Company smelter in Tamano, Japan, and the general ventilation or building evacuation system applied at the ASARCO-El Paso copper smelter.

The gas tracer study performed on the converter air curtain system at ASARCO-Tacoma indicates that approximately 95 percent of the converter fugitive emissions from all operating modes is captured by the system. Visual observations of the operation of this system verify this measured capture efficiency, but also indicate that operating practices play an important role in attaining this efficiency consistently. EPA has concluded that this efficiency can be achieved with a properly operated air curtain secondary hooding system in combination with proper operating practices.

The visual observations made at Tamano on the air curtain secondary hood indicate that the application of such a system on a conventional Pierce-Smith converter should result in an overall capture efficiency of at least 90 percent. As reported previously, no visible emissions were observed during either slag blowing or copper blowing, which in combination account for nearly 80 percent of a typical converter cycle. Although emissions were observed penetrating the air curtain during matte charging, these emissions were judged to be negligible, consisting of small puffs ranging from 0 to 10 percent opacity. Emissions observed during (slag and blister) pouring operations were somewhat more substantial, varying from 0 to 35 percent opacity.

However, as previously indicated, these emissions were generally observed to escape through a narrow opening which existed between the enclosure doors and roof. The smelter representatives indicated that a tighter seal between the doors and roof would result in a significant improvement.

Conclusions regarding the potential effectiveness of the building evacuation system used at the ASARCO-El Paso smelter are based primarily on engineering judgment. Providing the building is properly enclosed and adequate ventilation rates are applied, essentially 100 percent capture should be possible. However, due to the need for openings in the building for access and makeup air, a more conservative estimate of 95 percent capture is considered more reasonable. The fact that this system has shown less than satisfactory performance at the El Paso facility highlights the difficulty of designing an evacuation system which will provide a controlled ventilation air supply for all of the emission sources in the building. Fugitive sources have generally been found to be more successfully controlled by the use of local ventilation (hooding) techniques.

With regard to the collection of fugitive arsenic emissions in a control device, the emission measurements conducted across the baghouse facility serving the converter building evacuation system at ASARCO-El Paso showed that an arsenic collection efficiency of 96 percent or higher was readily achievable, even though the measured inlet concentrations were extremely low, averaging only 3.3 mg/Nm^3 (0.0014 gr/scf).

3.3 REFERENCES

1. Vallance, R.H. Arsenic In: A Text-Book of Inorganic Chemistry, Friend, J.N. (ed.), London. Charles Griffin and Co., Limited. 1938. p. 129-131.
2. Handbook of Chemistry and Physics, 43rd Edition. The Chemical Rubber Publishing Company. 1961. p. 2373.
3. Behrens, R.G., and G.M. Rosenblatt. Vapor Pressure and Thermodynamics of Octahedral Arsenic Trioxide (Arsenolite). Journal of Chemical Thermodynamics. 4:175-190. 1972.
4. Schwitzgabel, K., et. al. Trace Element Study at a Primary Copper Smelter. Prepublication Copy. U.S. Environmental Protection Agency. Contract No. 68-01-4136. January 1978.
5. Control Techniques for Particulate Air Pollutants. U.S. Environmental Protection Agency. Publication No. AP-51. January 1969. p. 108-122.
6. Southern Research Institute. An Electrostatic Precipitator Systems Study. Final Report to the National Air Pollution Control Administration. Contract No. CPA22-69-73. October 30, 1970. p. 20.
7. Reference 6, p. 22.
8. Control Techniques for Lead Emissions, Volume I: Chapters 1-3. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA-450/2-77-012. December 1977. p. 2-30.
9. Background Information for New Source Performance Standards: Primary Copper, Zinc, and Lead Smelters, Volume I: Proposed Standards. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA-450/2-74-002a. October 1974. p. 4-10.
10. Reference 11, p. 4-9.
11. Danielson, John A. Air Pollution Engineering Manual. 2nd Edition. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. AP-40. May 1973.
12. Hemeon, W.C.L. Plant and Process Ventilation. New York. The Industrial Press. Second Edition, 1963.
13. Dynaforce Corporation Brochure. Air Curtains for Industry. New York. June 1978.

14. Powlesland, J.W. Air Curtains in Controlled Energy Flows - To Stop or Regulate Air Flows - To Contain and Convey Airborne Contaminants. Presented at the 22nd Annual Industrial Ventilation Conference. February 1973.
15. Katari, V., et.al. Pacific Environmental Services, Inc., Plant visit report for ASARCO Copper Smelter, Tacoma, Washington, during June 24 to 26, 1980. Pacific Environmental Services, Inc. July 14, 1980. p. 4.
16. PEDCo Environmental Specialists, Inc. Secondary Hooding for Pierce-Smith Converters. U.S. Environmental Protection Agency. EPA Contract No. 68-02-1321. December 1976.
17. Iverson, R. Visual Evaluation of the Converter Secondary Hood System at the Phelps Dodge-Ajo Smelter. U.S. Environmental Protection Agency.
18. Movie on the Operation of the Swing-Away Hood Supplied by the Nippon Mining, Ltd. of Tokyo, Japan.
19. Devitt, T.W. PEDCo Environmental, Inc. Control of Copper Smelter Fugitive Emissions. U.S. Environmental Protection Agency. Cincinnati, OH. Publication No. EPA-600/2-80-079. May 1980.
20. Brochure on the Saganoseki Smelter and Refinery by Nippon Mining Company, Ltd., Japan. 1978.
21. Mitsubishi Metal Corporation. Guide to Nonferrous Metals Smelting and Refining Technologies. (Pamphlet). Japan.
22. Katari, V. and I.J. Weisenberg. Trip Report--Visit to Hiibi Kyodo Smelting Company's Tamano Smelter during the week of March 10, 1980. Pacific Environmental Services, Inc.
23. Chetvcov, V.A., et al. Ventilation in the Nonferrous Metallurgy. Moscow. Metallurgia Publishing Organization. 1968. p. 72.
24. Blair, T.R., et al. Electric Arc Furnace Fume Control at Lone Star Steel Company. Paper presented at the 71st Annual meeting of the Air Pollution Control Association. June 25-30, 1978. p. 3.
25. Baturin, V.V. Fundamentals of Industrial Ventilation. Translated by O.M. Blunn. Pergamon Press. Third Edition. 1972.
26. Grassmuck, G. Applicability of Air Curtains as Air Stopping and Flow Regulators in Mini Ventilation. C.I.M. Bulletin. No. 691. 62:1175-1185. November 1969.

27. Correspondence from Mr. Moto Goto, Smelter Manager, Naoshima Smelter, Japan, to Mr. I.J. Weisenberg, Pacific Environmental Services, Inc. October 1, 1978. Capabilities of air curtain control system.
28. ASARCO Design Report. Converter Secondary Hooding for the Tacoma Plant. Prepared by ASARCO Central Engineering Dept., Salt Lake City, UT. January 22, 1982.
29. PEDCo Environmental, Inc. Emission Test Report - Evaluation of an Air Curtain Hooding System for a Primary Copper Converter, ASARCO, Inc., Tacoma, Washington. Volume I. EPA Contract Nos. 68-03-2924 and 68-02-3546. Preliminary Draft. March 1983.
30. Davis, J.A. Unidirectional Flow Ventilation System. Presented at the 104th Annual AIME Meeting. New York. February 18, 1975. p. 3, 4.
31. Telecon. Katari, Vishnu, Pacific Environmental Services, Inc., with Sieverson, Jim, ASARCO, Incorporated. February 25, 1983. Copper smelter fugitive control system.
32. TRW Environmental Engineering Division. Emission Testing of ASARCO Copper Smelter, Tacoma, Washington. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-12. April 1979. p. 4-5.
33. Reference 32, p. 10-12.
34. Harris, D.L., Monsanto Research Corporation. Air Pollution Emission Test - Particulate and Arsenic Emission Measurements from a Copper Smelter. Anaconda Mining Company, Montana. U.S. Environmental Protection Agency. EMB Report No. 77-CUS-5. April 18-26, 1977. p. 5-16.
35. Reference 32, p. 6.
36. Harris, D.L., Monsanto Research Corporation, Dayton Laboratory. Particulate and Arsenic Emission Measurements From a Copper Smelter. U.S. Environmental Protection Agency. EMB Report No. 77-CUS-6. June 20-30, 1977. p. 18-25.
37. TRW Environmental Engineering Division. Air Pollution Emission Test, ASARCO Copper Smelter, El Paso, Texas. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-7. April 25, 1978. p. 13.
38. Larkin, R. and J. Steiner, Acurex Corporation/Aerotherm Division. Arsenic Emissions at Kennecott Copper Corporation, Hayden, Arizona. U.S. Environmental Protection Agency Report No. 76-NFS-1. May 1977. p. 2-2.

39. Reference 36, p. 14-17.
40. Rooney, Thomas, TRW Environmental Engineering Division. Emission Testing of Phelps-Dodge Copper Smelter, Ajo, Arizona. U.S. Environmental Protection Agency. EMB Report No. 78 CUS-11. EPA Contract No. 68-02-2812. Work Assignment No. 15. March 1979. p. 5-6.
41. Reference 15, p. 4.
42. Reference 29, p. 4-66.
43. Vervaert, A. and J. Nolan, U.S. Environmental Protection Agency and Puget Sound Air Pollution Control Agency. Log Book Nos. 1 and 2, Observations of Converter Secondary Hood Test at ASARCO, Tacoma. January 18-22, 1983.
44. Reference 22, p. 3.
45. Reference 37, p. 7-8.
46. Reference 37, p. 4-5.

4.0 MODEL PLANTS, REGULATORY BASELINE, AND REGULATORY ALTERNATIVES

Arsenic has been listed as a hazardous air pollutant under Section 112 of the Clean Air Act (National Emission Standards for Hazardous Air Pollutants). To protect public health from unreasonable risks associated with exposure to airborne arsenic, standards are being developed to decrease arsenic emissions from primary copper smelters which process low-arsenic content feed. This section defines the regulatory baseline, presents the alternative ways that EPA can regulate arsenic emissions from the affected sources, and describes the 14 existing low-arsenic throughput copper smelters for analysis of the environmental, economic, and energy impacts of the regulatory alternatives on the industry.

The technical and economic impacts of arsenic regulatory alternatives on primary copper smelters are measured as incremental changes beyond the conditions that would exist in the absence of NESHAP regulations. These conditions are commonly referred to collectively as a baseline. This section defines such a baseline as it applies to the primary copper smelting industry in general and to the low-arsenic throughput smelters specifically.

In the following analysis, baseline is chosen to represent existing process and control equipment except in the case of four smelters which are scheduled to undergo modernization. For these four smelters, ASARCO-Hayden, Phelps Dodge-Ajo, Phelps Dodge-Morenci, and Kennecott-Hurley, baseline is defined as process and control equipment after modernization. The configurations of these smelters after modernization are described in Section 4.3.

4.1 REGULATORY CONSIDERATIONS

The low-arsenic throughput copper smelters are subject to existing and forthcoming regulations arising from the national ambient air quality standards (NAAQS) for suspended particulates, sulfur oxides

and lead; wastewater effluent limitations; hazardous waste disposal requirements; and regulations directed at occupational safety and health. Compliance with some of these regulations may coincidentally decrease arsenic emissions or affect the manner in which arsenic emissions are discharged into the atmosphere, even though they were not necessarily developed with that objective. Either a change in the quantity of arsenic emitted, or the manner in which arsenic is emitted (high versus low level discharge of emissions), will necessarily affect the ambient concentrations of airborne arsenic near these smelters. Furthermore, the cost of compliance with these regulations will affect the economic viability of individual smelters and the industry as a whole, and thus the affordability of arsenic controls.

For the purpose of relating the timings of other regulatory requirements to the timing of an arsenic NESHAP, January 1986 is projected as the compliance date with the arsenic NESHAP. The date is based upon a January 1984 promulgation for the regulation and assumes that the full 2-year waiver of compliance available under the general provisions of 40 CFR 61 would be applied for and granted by EPA.

Regulations to be examined in formulating the regulatory baseline include the following:

- National Ambient Air Quality Standards (NAAQS) under the Clean Air Act (CAA) for sulfur dioxide, total suspended particulates, and lead;
- Occupational Safety and Health Administration (OSHA) regulations for inorganic arsenic;
- Effluent limitation guidelines under the Clean Water Act (CWA); and
- Hazardous waste disposal regulations under the Resource Conservation and Recovery Act (RCRA).

It should be noted that there are inherent uncertainties in estimating the control requirements and compliance dates associated with these regulations. However, these uncertainties aside, such estimates are necessary in order to make a reasonable attempt at assessing the impacts of a possible arsenic NESHAP regulation for low-arsenic primary copper smelters.

4.1.1 Clean Air Act

Under Section 109 of the Clean Air Act, EPA has set national ambient air quality standards (NAAQS) for certain "criteria" pollutants. The criteria pollutants emitted by primary copper smelters are sulfur dioxide, particulates, and lead. The NAAQS are to be met through the establishment of State implementation plans (SIP's) governing emission sources of these pollutants. The plans call for "combinations of emission limitations and other measures such that the total mix of these measures would result in the attainment and maintenance of air quality standards."¹

The following subsections address each of the three criteria pollutants emitted by primary copper smelters and the control measures developed under SIP's.

4.1.1.1 Sulfur Dioxide. The initial SIP requirements for the control of SO₂ have undergone considerable reshaping by the courts and by Congress since first developed by the States and approved by EPA.

Congress passed the Clean Air Act Amendments of 1977 which generally prohibited the use of dispersion techniques in SIP's to meet ambient standards and required the installation of constant controls for the meeting of NAAQS as expeditiously as practicable. An exception to the prohibition of dispersion techniques applied to primary copper, zinc, or lead smelters which were eligible for a primary nonferrous smelter order (NSO) under Section 119 of the Clean Air Act.² The NSO permits a smelter a temporary deferral, up to as late as January 1, 1993, from compliance with its SIP for SO₂ emission limitations, and permits the smelter to meet ambient air quality standards through the use of constant control technology in combination with interim dispersion-dependent control techniques including tall stacks and supplementary control systems. NSO recipients are to be determined on a case-by-case basis. To be eligible for the deferral, each smelter must, among other things, pass an economic test by which it demonstrates that it is economically incapable of implementing constant controls.

Table 4-1 summarizes the applicable SO₂ regulations and the compliance status of the various smelters. It can be seen that three smelters are in compliance with the applicable SIP regulation. Of the remaining 11 smelters, six are under NSO's (and/or consent decrees),

Table 4-1. STATE IMPLEMENTATION PLANS (SIP'S) FOR SULFUR DIOXIDE AFFECTING COPPER SMELTERS AND COMPLIANCE STATUS

Smelter	Regulation	Compliance Status	Reference
ASARCO-EI Paso, TX	131.04.01.004	Out of compliance	3
ASARCO-Hayden, AZ	R9-3-515.C.1.b	Currently under NSO ^a	4
Tennessee Chemical Co.- Copperhill, TN	1200-3-19-.19	In compliance	5
Inspiration-Miami, AZ	R9-3-515.C.1.d.	Stack emissions-in compliance Fugitive emissions-out of compliance	4
Kennecott-Garfield, UT	4.3.1, 4.3.2, 4.3.4	None-SIP not yet promulgated	6
Kennecott-Hayden, AZ	R9-3-515.C.1.c	Stack emissions-in compliance Fugitive emissions-out of compliance	4
Kennecott-Hurley, NM	652	Currently under NSO	7
Kennecott-McGill, NV	8.1 and 14	Currently under NSO	8
Magma-San Manuel, AZ	R9-3-515.C.1.a	Currently under NSO	4
Phelps-Dodge-Ajo, AZ	R9-3-515.C.1.e	Stack emissions-in compliance Fugitive emissions-out of compliance	4
Phelps Dodge-Douglas, AZ	R9-3-515.C.1.f	Currently under NSO	4
Phelps Dodge-Hidalgo, NM	652	In compliance	7
Phelps Dodge-Morenci, AZ	R9-3-515.C.1.g	Currently under NSO	4
Copper Range- White Pine, MI	Rule 402	In compliance	9

^aNonferrous smelter orders.

one is awaiting promulgation of an SIP, and four are currently out of compliance. For the seven Arizona smelters, the new Multi-Point Rollback limits introduce uncertainty with regard to control equipment requirements. Uncertainties associated with timing for final achievement of compliance under the NSO program make it difficult to estimate the effect of the NSO's on regulatory baseline. For the purpose of baseline analysis, the following assumptions were made with regard to probable effects of existing SO₂ regulations on an arsenic NESHAP:

1. The terms of the consent decrees signed by three of the smelters should bring them into compliance.
2. Because of uncertainties within the NSO program, requirements for SO₂ control under this program were not considered in the baseline.
3. For the six smelters either out of compliance, or of unknown compliance status, it will be assumed that future SO₂ controls will be implemented sometime beyond the implementation of arsenic controls.

4.1.1.2 Total Suspended Particulates. The original date specified in the Clean Air Act of 1970 for attaining the primary NAAQS for total suspended particulates was July 1, 1975. That date was extended by the Clean Air Act Amendments of 1977 to no later than 3 years after EPA's approval of revised SIP's for areas not in attainment with the primary NAAQS at the earlier date.

Table 4-2 summarizes the current applicable TSP regulations and the compliance status of affected smelters. It can be seen that four smelters are currently in compliance with the SIP's, four are out of compliance, four are under compliance schedules, one is awaiting promulgation of an SIP, and the status of the remaining smelter is unknown.

Total suspended particulate controls are not included in the baseline of the four smelters which are out of compliance. It is assumed that the four smelters which are under compliance schedules will come into compliance within the time frame that an arsenic NESHAP would be effective, therefore, the regulatory baseline for these smelters includes the controls to comply with the SIP.

Table 4-2. STATE IMPLEMENTATION PLANS (SIP'S) FOR TOTAL SUSPENDED PARTICULATES AFFECTING COPPER SMELTERS AND COMPLIANCE STATUS

Smelter	Regulation	Compliance Status	Reference
ASARCO-El Paso, TX	111.51, 111.52	Out of compliance	3
ASARCO-Hayden, AZ	40 CFR 52.126(b)	Under compliance schedule	4
Tennessee Chemical Co.- Copperhill, TN	1200-3-7-.02-(3)	In compliance	5
Inspiration-Miami, AZ	40 CFR 52.126(b)	In compliance	4
Kennecott-Garfield, UT	3.2.3	None-SIP not yet promulgated	6
Kennecott-Hayden, AZ	40 CFR 52.126(b)	In compliance	4
Kennecott-Hurley, NM	506	In compliance with mass emission rate, not in compliance with BAT	7
Kennecott-McGill, NV	7.2.3	Out of compliance	8
Magma-San Manuel, AZ	40 CFR 52.126(b)	Out of compliance	4
Phelps-Dodge-Ajo, AZ	40 CFR 52.126(b)	Under compliance schedule	4
Phelps Dodge-Douglas, AZ	7-1-3.6	Out of compliance	4
Phelps Dodge-Hidalgo, NM	506	Under compliance schedule	7
Phelps Dodge-Morenci, AZ	7-1-3.6	Under compliance schedule	4
Copper Range-White Pine, MI	Rules 301 and 331	Unknown - never tested	9

4.1.1.3 Lead. The national ambient air quality standard for lead of $1.5 \mu\text{g}/\text{m}^3$ was promulgated on October 5, 1978 (40 CFR 51.80). Table 4-3 presents the lead SIP compliance status of the low-arsenic throughput copper smelters. Both of the smelters which are under SIP's are currently in compliance. The remaining 12 smelters are in States in which there are either no nonattainment areas for the lead NAAQS, or in which no lead SIP has been promulgated. For purposes of baseline analysis, it is assumed that neither existing nor upcoming lead SIP's will affect arsenic air emissions from the smelters under consideration, or cause a significant economic burden concurrent with an arsenic NESHAP.

4.1.2 Arsenic Regulation by the Occupational Safety and Health Administration

On May 5, 1978, the U.S. Occupational Safety and Health Administration (OSHA) promulgated standards for occupational exposure to inorganic arsenic.¹⁰ The standards limit occupational exposure to $10 \mu\text{g}/\text{m}^3$, averaged over any 8-hour period. The regulations require the use of engineering and work practice controls. In the event that engineering controls are not sufficient to reduce exposures to or below the standard, the engineering controls must be used to reduce exposures to the lowest level achievable and should be supplemented by the use of respirators and other necessary personal protective equipment. Primary copper smelters were required to monitor for violations and submit a compliance plan to OSHA by December 1, 1978.

The OSHA requirement is a concentration limit and does not specify the sources to be controlled or the equipment to be utilized in control. Compliance plans with OSHA will require the application of capture systems on various fugitive sources, in addition to worker protection programs such as the use of respirators, protective work clothing, improved housekeeping practices, hygiene facilities and practices, and medical surveillance. ASARCO has recently negotiated tripartite agreements with OSHA and the United Steelworkers of America which specify controls and work practices designed to decrease worker exposure to inorganic arsenic at the three ASARCO smelters.^{11,12,13} The El Paso agreement¹¹ specifies the installation of local ventilation hoods for slag tapping. This requirement is incorporated into the baseline

Table 4-3. STATE IMPLEMENTATION PLANS (SIP'S) FOR LEAD AFFECTING COPPER SMELTERS AND COMPLIANCE STATUS

Smelter	Regulation	Compliance Status	Reference
ASARCO-El Paso, TX	No SIP-Currently under study	--	3
ASARCO-Hayden, AZ	No SIP	--	4
Tennessee Chemical Co.-Copperhill, TN	1200-3-22-.03	Regulation currently in proposal phase	5
Inspiration-Miami, AZ	No SIP	--	4
Kennecott-Garfield, UT	SIP recently approved	In compliance	6
Kennecott-Hayden, AZ	No SIP	--	4
Kennecott-Hurley, NM	No SIP	--	7
Kennecott-McGill, NV	Article 12	In compliance	8
Magma-San Manuel, AZ	No SIP	--	4
Phelps-Dodge-Ajo, AZ	No SIP	--	4
Phelps Dodge-Douglas, AZ	No SIP	--	4
Phelps Dodge-Hidalgo, NM	No SIP	--	7
Phelps Dodge-Morenci, AZ	No SIP	--	4
Copper Range-White Pine, MI	No SIP	--	9

for the El Paso smelter. Collection of the captured slag tapping emissions is not specified in the OSHA compliance plan. The Hayden agreement¹² specifies that all engineering controls currently in existence which limit occupational arsenic exposure be used, but does not require the installation of any new fugitive emissions capture systems at ASARCO-Hayden. OSHA has also negotiated compliance plans with two Kennecott smelters (Garfield and McGill), but these agreements have not yet been signed, nor is signature imminent, and OSHA has no plans to negotiate compliance plans with any other copper smelters at this time.¹⁴ Therefore, capture of slag tapping fugitive emissions at ASARCO-El Paso is the only OSHA requirement which must be incorporated into the regulatory baseline of an arsenic NESHAP.

4.1.3 Clean Water Act

Water pollution control regulations affect all areas of the primary copper industry, including mining, milling, smelting, refining, and acid plants. These regulations do not affect arsenic air emissions. The discussion of water pollution control regulations under the Clean Water Act is divided into those which are based on the best practicable control technology (BPT) requirements [Section 301(b)(1)(A)], and those which are based on the best available technology (BAT) and best conventional pollution control technology (BCT) [Section 301(b)(2)].

Potential water pollution originating from the low-arsenic throughput primary copper smelters will be regulated by EPA's proposed effluent limitations guidelines for nonferrous metals manufacturing.¹⁵ Effluents from the smelters will be covered by two subcategories: primary copper smelting and metallurgical acid plants. The proposed regulations for the primary copper smelting subcategory will amend promulgated BAT (40 FR 8523) to conform BAT to promulgated BPT (45 FR 44926), which is more stringent. The proposed metallurgical acid plant regulations set forth BAT effluent mass limitations for metallurgical acid plants, including copper smelter acid plants, based on promulgated BPT (45 FR 44926).

4.1.4 Resource Conservation and Recovery Act (RCRA)

On May 19, 1980, EPA promulgated regulations under the Resource Conservation and Recovery Act for the disposal of hazardous substances from metallurgical and other process industries (45 FR 33066). EPA

identified the acid plant blowdown slurry/sludge resulting from the thickening of blowdown slurry at primary copper smelters as a hazardous waste because of its lead and cadmium content. However, the extent to which acid plant blowdown will be subject to regulations for treatment and disposal is unknown. No regulations under RCRA will affect arsenic air emissions, however, and it is unlikely that any of the smelters will suffer a significant economic impact as a result of RCRA regulations.

4.2 BASELINE AND REGULATORY ALTERNATIVES

This section defines in general terms the baseline employed for the impacts analysis in succeeding chapters of this document, and presents the regulatory alternatives along with the technology selected for each alternative.

4.2.1 Definition of Baseline

For the purposes of the analysis presented in this document, "baseline" includes only those existing air pollution controls which were installed as of January 1983 or were required by existing legal actions. Three smelters, (Phelps Dodge-Ajo and -Morenci, and ASARCO-Hayden) currently are operating under consent decrees^{16,17} to install new furnace configurations and acid plant control equipment for SO₂ emissions. Final compliance dates for these consent decrees have been established as 1985. Since these controls are mandated by the courts and final compliance will be in the near future, the "consent decree configurations" were treated as though they were existing configurations, and were incorporated into the baseline.

The Kennecott-Hurley smelter is currently undergoing voluntary upgrading of the furnace configuration and the installation of acid plant controls. This work has already begun and is expected to be completed in the same time frame as the smelters operating under a consent decree.¹⁸ For this reason, the smelter configuration after modernization was taken as the baseline configuration.

4.2.2 Description of the Regulatory Alternatives

The four regulatory alternatives represent application of inorganic arsenic controls on various emission points at the smelters and are characterized by the control equipment that would be required to meet these levels of control. Alternatives II, III, and IV each include

baseline controls but are otherwise not additive, e.g., Alternative III does not include what was required by Alternative II, etc.

Alternative II would require the control of process arsenic emissions. As discussed in Section 3.1.1.1, the arsenic collection efficiency of any particulate control device is a function of temperature and the corresponding arsenic saturation concentration, and the arsenic concentration of the particular gas stream. As can be seen from the sample calculation presented in Section 3.1.1.1, for streams with lower arsenic concentrations, cooling the gas stream prior to its entering a particulate control device would have no effect on arsenic removal efficiencies. For these smelters, Alternative II would not require installation of additional control equipment beyond the baseline configuration. For those smelters with higher arsenic concentrations in process gas streams, control would be effected by operating a particulate control device at less than 121°C (250°F), with flue gas cooling upstream of the control device.

Alternative III would require the capture and collection of fugitive arsenic emissions from converter operations. This alternative is based on the use of an air curtain secondary hood or equivalent for the capture of fugitive emissions from the converters, and a particulate control device (baghouse or equivalent technology) for the collection of the captured emissions.

Alternative IV would require the capture and collection of fugitive emissions from calcine discharge, matte tapping, and slag tapping operations. Under this alternative the capture of the fugitive emissions at each emission point would be accomplished using localized ventilation hoods, with the emissions being routed to a particulate control device (baghouse or equivalent technology) for collection.

Alternative V would require the elimination of all arsenic emissions at copper smelters. To accomplish this alternative the smelters would be forced to process ores which were virtually free of arsenic content. This regulatory alternative would therefore require the closure of all existing primary copper smelters.

4.3 BASELINE CONFIGURATION, BASELINE ARSENIC EMISSIONS, AND REGULATORY ALTERNATIVES FOR MODEL PLANTS

The diversity of operational parameters among the 14 low-arsenic throughput copper smelters makes it impractical to define "generic" model plants. Therefore, 14 model plants were chosen, representing the baseline configurations, as defined in Section 4.2.1, of the 14 low-arsenic copper smelters. Section 4.3.1 presents arsenic emission estimates, process and fugitive, for the model plant baseline configurations, while Section 4.3.2 is a plant-by-plant description of the baseline configurations along with a summary of what would be required of each model plant under each of the regulatory alternatives.

4.3.1 Baseline Arsenic Emissions

This section presents arsenic emission estimates for the baseline configuration of each model plant.

4.3.1.1 Process Emissions. Table 4-4 presents process arsenic emission estimates for the model plant baseline configurations, after control. As discussed in Section 2.0, process equipment exhaust gas arsenic content was read from the arsenic material balances supplied in Appendix F. Arsenic removal efficiency of control devices at each of the 14 existing smelters was taken either from the company-supplied material balances, by comparing indicated inlet arsenic loading to indicated emissions, or from the following control efficiencies determined during EPA's performance evaluations of various types of particulate control devices. "Cold" devices (121°C, 250°F or below, inlet) were deemed to be 96 percent efficient, while "hot" (above 150°C, 300°F, inlet) control devices were assigned an arsenic removal efficiency of 30 percent. Acid plants, due to the requirement for extensive gas precleaning and conditioning, were ascribed a control efficiency of 99 percent.

4.3.1.2 Fugitive Emissions. Table 4-5 presents fugitive arsenic emissions estimates for the model plant baseline configurations. Emission rates in absence of control were taken from Table 2-17. At 3 of the 14 smelters, control of one or more of the fugitive gas streams is practiced. Details of baseline capture and control of fugitive emissions are provided in the plant-by-plant discussion which follows.

Table 4-4. SUMMARY OF BASELINE PROCESS ARSENIC EMISSION ESTIMATES FOR LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS

Smelter	Emission Source	Exit Gas Arsenic Content kg/hr	Control Equipment		Overall Control Efficiency (percent)	Emission Rate kg/hr
			Type	Efficiency (percent)		
ASARCO-El Paso	MIR REV CONV	86.6 54.9 76.2	1. ESP, 2. Acid Plant Cold ESP	1. 60, 2. 99 97.5	99.9 97.5 99.9	0.04 1.4 0.03
	FF CONV	157.0 45.0	1. ESP, 2. Acid Plant 1. ESP, 2. Acid Plant	1. 96, 2. 99 1. 96, 2. 99 1. 97, 2. 99	99.9 99.9	0.16 0.04
Tennessee Chemical Co., Copperhill	FBR	0.2	1. Scrubber, 2. ESP, 3. Acid Plant	1. 50, 2. 100, 3. 99	100	0
	EF	0.4	1. Scrubber, 2. ESP, 3. Acid Plant	1. 50, 2. 100, 3. 99	100	0
Inspiration- Miami	CONV	0.5	1. Scrubber, 2. ESP, 3. Acid Plant	1. 50, 2. 100, 3. 99	100	0
	EF CONV	4.5 1.5	1. ESP, 2. Acid Plant 1. ESP, 2. Acid Plant	1. 30, 2. 99 1. 30, 2. 99	99.4 98.9	0.03 0.02
Kennecott-Garfield	NOR	115.0	1. Cyclones, 2. ESP's 3. Acid Plant	1. 20, 2. 60, 3. 95	98.0	1.7
	CONV	6.0	1. ESP's, 2. Acid Plant	1. 60, 2. 95	98.0	0.1
Kennecott-Hayden	FBR REV CONV	1.9 5.3 5.0	1. Scrubber, 2. Acid Plant ESP 1. ESP, 2. Scrubber 3. Acid Plant	1. 90, 2. 99 40 1. 40, 2. 90, 3. 99	99.9 40 99.9	0.02 3.2 0.03
	FF CONV	1.3 0.4	1. ESP, 2. Acid Plant 1. ESP, 2. Acid Plant	1. 75, 2. 99 1. 25, 2. 99	99.9 99.9	0.0004 0.0001
Kennecott-McGill	REV CONV	18.6 35.6	ESP Multiclones	30 7	30 7	12.8 33.0
	REV CONV	1.8 0.5	ESP 1. ESP, 2. Acid Plant	30 1. 30, 2. 99	30 99.2	1.3 0.003
Phelps Dodge-Ajo	OXREV CONV	45.3 2.3	1. ESP, 2. Acid Plant 1. ESP, 2. Acid Plant	1. 25, 2. 90 1. 25, 2. 90	92.0 92.0	3.5 0.2
Phelps Dodge- Douglas	MIR REV CONV	2.2 0.9 3.2	ESP ESP ESP	30 30 30	30 30 30	1.5 0.7 2.2
Phelps Dodge- Hidalgo	FF CONV	13.7 0.9	1. ESP, 2. Acid Plant 1. ESP, 2. Acid Plant	1. 30, 2. 98 1. 30, 2. 98	99.9 99.9	0.2 0.01
Phelps Dodge- Torenci	OXREV CONV	4.3 5.3	1. ESP, 2. Acid Plant 1. ESP, 2. Acid Plant	1. 30, 2. 98 1. 30, 2. 98	99.9 99.9	0.06 0.08
Copper Range- White Pine	REV CONV	0.4 0.2	ESP Hailon Flue	70 60	70 60	0.1 0.1

^a Sources: MIR - Multihearth Roaster
REV - Reverberatory furnace
CONV - Converters
FF - Flash Furnace
FBR - Fluid Bed Roaster
EF - Electric Furnace
NOR - Noranda Reactor
OXREV - Oxygen-Sprinkle Reverberatory Furnace

Table 4-5. SUMMARY OF BASELINE FUGITIVE ARSENIC EMISSION ESTIMATES FOR LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS

Smelter	Emission Source	Emission Rate, Absence of Control kg/hr	Control Equipment	Control Capture	Control Efficiency (Percent) Collection	Emission Rate kg/hr
ASARCO-El Paso	CT	0.07	Cold ESP	90	97.5	0.009
	ST	0.05	-	90	0	0.05
	HT	0.7	Baghouse	90	97.5	0.09
	CONV	11.4	Baghouse	75	96	3.2
	AF	1.3	Baghouse	75	96	0.4
ASARCO-Hayden	FDH	0.26	-	0	0	0.26
	ST	0.1	Cold ESP	90	96	0.01
	HT	1.5	Cold ESP	90	96	0.2
	CONV	6.8	Cold ESP	50	96	3.5
	AF	2.2	-	0	0	2.2
Tennessee Chemical Co.-Copperhill	FDH	0.2	-	0	0	0.2
	ST	0.0004	-	90	0	0.0004
	HT	0.01	-	90	0	0.01
	CONV	0.08	-	0	0	0.08
	FDH	0.0006	-	0	0	0.0006
Inspiration-Miami	ST	0.01	-	0	0	0.01
	HT	0.08	-	90	0	0.08
	CONV	0.22	-	0	0	0.22
	AF	0.08	-	0	0	0.08
	FDH	0.002	-	0	0	0.002
Kennecott-Garfield	ST	0.03	-	90	0	0.03
	HT	0.2	-	90	0	0.2
	CONV	0.9	-	50	0	0.9
	AF	1.5	-	0	0	1.5
	FDH	0.2	-	0	0	0.2
Kennecott-Hayden	ST	0.002	-	90	0	0.002
	HT	0.11	-	90	0	0.11
	CONV	0.0	-	0	0	0.8
	AF	0.01	-	0	0	0.01
	FDH	0.004	-	0	0	0.004
Kennecott-Hurley	ST	0.001	-	0	0	0.001
	HT	0.014	-	90	0	0.014
	CONV	0.05	-	0	0	0.054
	AF	0.02	-	0	0	0.018
	FDH	0.002	-	0	0	0.002
Kennecott-McGill	ST	0.02	-	90	0	0.02
	HT	0.5	-	90	0	0.5
	CONV	5.3	-	0	0	5.3
	AF	0.4	-	0	0	0.4
	FDH	0.02	-	0	0	0.02

Table 4-5. SUMMARY OF BASELINE FUGITIVE ARSENIC EMISSION ESTIMATES FOR LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS (concluded)

Smelter	Emission Source	Emission Rate, Absence of Control kg/hr	Control Equipment	Control Efficiency (Percent)		Emission Rate kg/hr
				Capture	Collection Overall	
Magma-San Manuel	ST	0.0004	-	90	0	0.0004
	HT	0.01	-	90	0	0.01
	CONV	0.06	-	0	0	0.06
	AF	0.006	-	0	0	0.006
Phelps Dodge-Ajo	FDH	0.0007	-	0	0	0.0007
	ST	0.01	-	90	0	0.01
	HT	0.06	-	90	0	0.06
	CONV	0.3	-	30	0	0.3
Phelps Dodge-Douglas	AF	0.1	-	0	0	0.1
	FDH	0.01	-	0	0	0.01
	CT	0.005	Baghouse	90	94.9	0.0007
	ST	0.006	ESP	90	30	0.004
Phelps Dodge-Idaho	HT	0.06	ESP	90	30	0.04
	CONV	0.5	-	0	0	0.5
	AF	0.02	-	0	0	0.02
	FDH	0.002	-	0	0	0.002
Phelps Dodge-Florent	ST	0.003	-	90	0	0.003
	HT	0.02	-	90	0	0.02
	CONV	0.14	-	30	0	0.14
	AF	0.07	-	0	0	0.07
Copper Range-White Pine	FDH	0.004	-	0	0	0.004
	ST	0.004	-	90	0	0.004
	HT	0.1	-	90	0	0.1
	CONV	0.8	-	30	0	0.8
Copper Range-White Pine	AF	0.06	-	0	0	0.06
	FDH	0.009	-	0	0	0.009
	ST	0.0002	-	90	0	0.0002
	HT	0.006	-	90	0	0.006
Copper Range-White Pine	CONV	0.04	-	0	0	0.04
	AF	0.02	-	0	0	0.02
	FDH	0.004	-	0	0	0.004

^aSources: CT - Calcine Transfer
ST - Slag Tapping
HT - Matte Tapping
CONV - Converter Operations
AF - Anode Furnace
FDH - Flue Dust Handling, Transfer, and Conveying
Captured by building evacuation system.

4.3.2 Model Plant Baseline Configurations and Regulatory Alternatives

The following model plant descriptions present the baseline configuration, as defined in Section 4.2.1, for the 14 low-arsenic throughput copper smelters. The configurations described in this section were those used in calculating baseline arsenic emissions, and serve as the starting point for subsequent analyses of the incremental environmental, energy, and economic impacts of the regulatory alternatives.

4.3.2.1 ASARCO-El Paso. The baseline configuration is presented in Figure 4-1. Offgases from the 4 multihearth roasters pass through a spray chamber and electrostatic precipitator before treatment in an acid plant. Offgases from the single reverberatory furnace enter a spray chamber, followed by passage through an electrostatic precipitator (operated at 121°C, 250°F) and discharge from a stack. Offgases from the three converters are treated in a spray chamber-electrostatic precipitator for particulate removal and a sulfuric acid plant for SO₂ control. Calcine discharge fugitive emissions are captured by a local ventilation system and routed to the reverberatory furnace spray chamber. Slag tapping fugitives are presently neither captured nor controlled at the El Paso smelter, but a recent agreement with OSHA¹¹ will require installation of a capture system. Thus, for purpose of defining baseline, a slag tap fugitive emission capture system is assumed to be installed. Matte tapping fugitive emissions are captured and ducted to the reverberatory furnace spray chamber. Converter fugitives are captured by the building evacuation system and collected in a baghouse. It is estimated that the building evacuation capture efficiency is 75 percent, and that the building evacuation baghouse particulate collection efficiency is 96 percent.

Regulatory Alternative II would require no controls beyond baseline at ASARCO-El Paso, since baseline process controls represent best technology for arsenic control.

Regulatory Alternative III would require installation of air curtain secondary hoods for capture of converter fugitive emissions. The existing building evacuation baghouse is assumed to be used for collecting the captured emissions.

Regulatory Alternative IV would require collection of captured slag tapping fugitive emissions in an effective particulate matter



Figure 4-1. ASARCO-EI Paso Smelter Baseline Configuration

control device. For the purpose of analysis, it is assumed that the existing reverberatory furnace electrostatic precipitator will suffice.

4.3.2.2 ASARCO-Hayden. The baseline configuration (according to the consent decree, see Section 4.2.1) is shown in Figure 4-2. Process offgases from the INCO flash furnace are cleaned in a spray chamber, settling chamber, and electrostatic precipitator before treatment in an acid plant. Offgases from the five converters pass through cyclones (three per converter), a spray chamber, and electrostatic precipitator before treatment in an acid plant. Matte and slag tap fugitive emissions are captured by a local ventilation system and controlled in a cold electrostatic precipitator. Converter fugitives are captured in a secondary hood system (estimated to be 50 percent efficient) and controlled in a cold electrostatic precipitator.

Arsenic vapor pressure calculations for the fugitive emission control device show it to be equally efficient for arsenic and particulate collection at the given temperature and gas stream arsenic concentration.

Regulatory Alternative II would require no controls beyond baseline for ASARCO-Hayden, where the baseline configuration includes best technology for arsenic control.

Regulatory Alternative III would require installation of air curtain secondary hoods on the converters, and collection of captured emissions in the cold electrostatic precipitator used for fugitive emission collection in the baseline configuration.

Regulatory Alternative IV would require no controls beyond baseline for ASARCO-Hayden, since baseline matte and slag tapping fugitive emission controls to be installed at the smelter are considered best technology.

4.3.2.3 Tennessee Chemical Co.-Copperhill. Figure 4-3 shows the baseline configuration for the Tennessee Chemical Company smelter. Offgases from the fluid-bed roaster pass through a cyclone and, combined with offgases from the electric furnace and the two converters, are treated in either of two acid plants following standard gas cleaning. Matte and slag tapping fugitive emissions are captured by localized ventilation systems and vented to a stack. Converter fugitives are neither captured nor controlled.

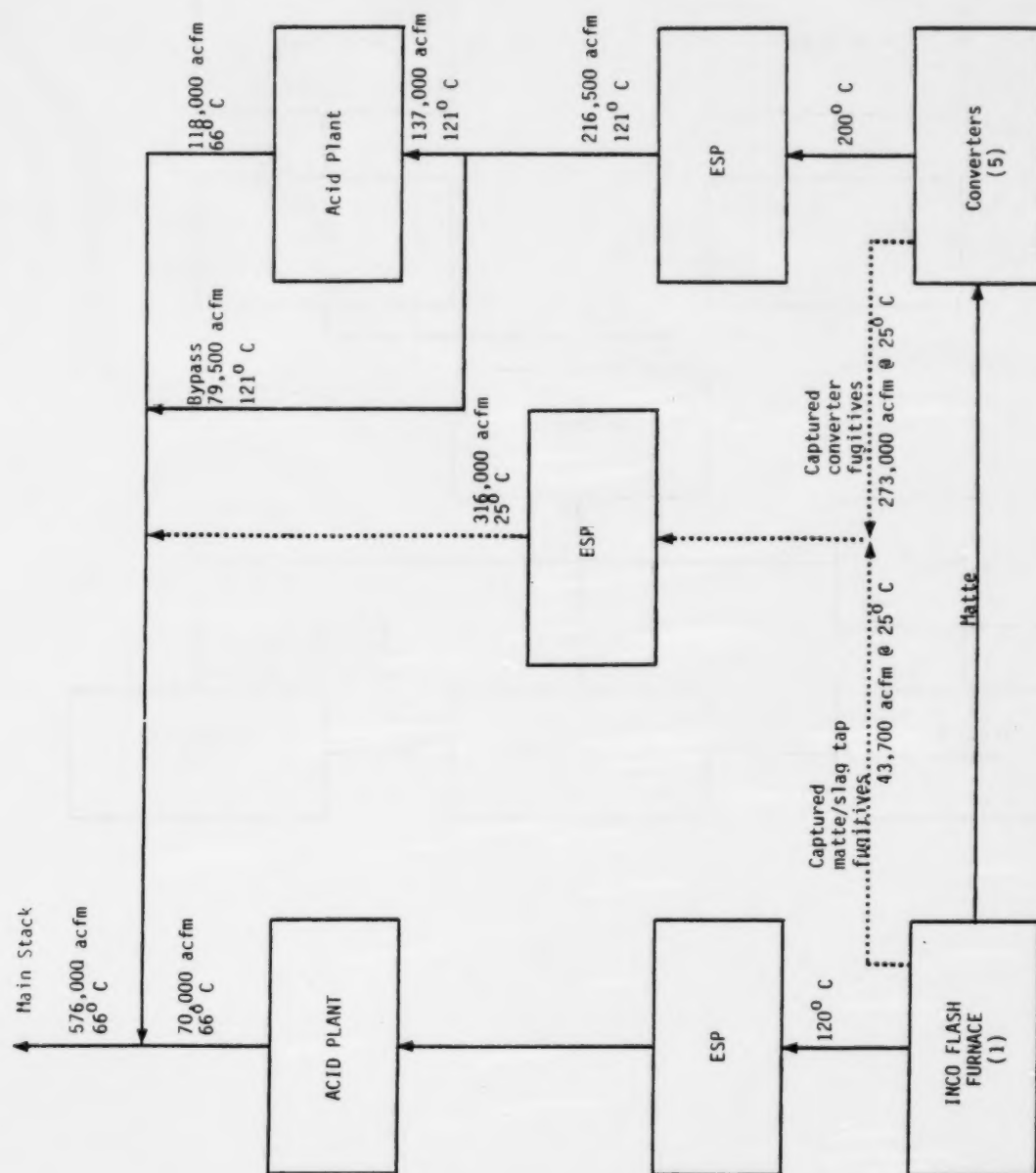


Figure 4-2. ASARCO-Hayden Smelter Baseline Configuration

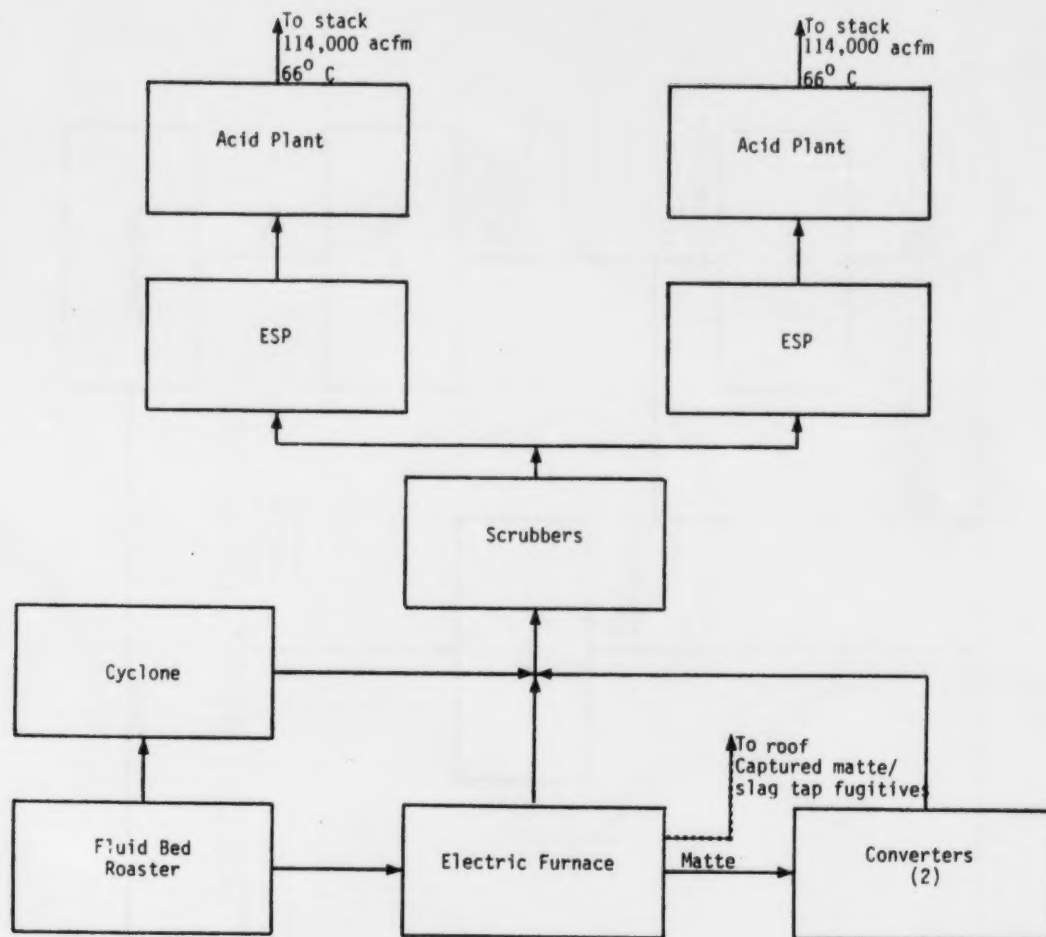


Figure 4-3. Tennessee Chemical Company
Smelter Baseline Configuration

Since process controls at the Copperhill smelter represent best technology for arsenic, Alternative II would require no additional controls beyond baseline.

Alternative III would require installation of air curtain secondary hoods on converters and a control device for collection of captured converter fugitive emissions.

Installation of a collection device for captured matte and slag tapping fugitive emissions would be required under Alternative IV.

4.3.2.4 Inspiration-Miami. The baseline configuration for Inspiration-Miami is depicted in Figure 4-4. Process emissions from both the single electric furnace and the five Hoboken converters pass through convection coolers, cyclones, and electrostatic precipitators before treatment in an acid plant. Fugitive emissions from slag tapping are neither captured nor controlled. Matte tapping emissions are captured by local ventilation and vented from the roof of the furnace building. Fugitive emissions from the converters are neither captured nor controlled.

Regulatory Alternative II would require no controls beyond baseline, since the baseline configuration represents best control of process arsenic emissions.

Alternative III would require installation of air curtain secondary hoods on the converters, and a particulate control device for collection of captured converter fugitive emissions.

Alternative IV would necessitate installation of a capture system for slag tapping fugitive emissions as well as a collection device for captured matte and slag tapping fugitive emissions.

4.3.2.5 Kennecott-Garfield. Kennecott-Garfield's baseline configuration is shown in Figure 4-5. Combined process offgases from the three Noranda reactors and the four converters pass through electrostatic precipitators (6 in series) and are then sent to any of four acid plants. Matte tap and slag tap fugitive emissions are captured by local ventilation systems and ducted to the main stack. Converter fugitives are captured by a secondary hooding system (assumed to 50 percent efficient) and vented to the main stack. In addition, the reactor and converter buildings are each ventilated by a fugitive emission roof capture system designed to handle emissions which have

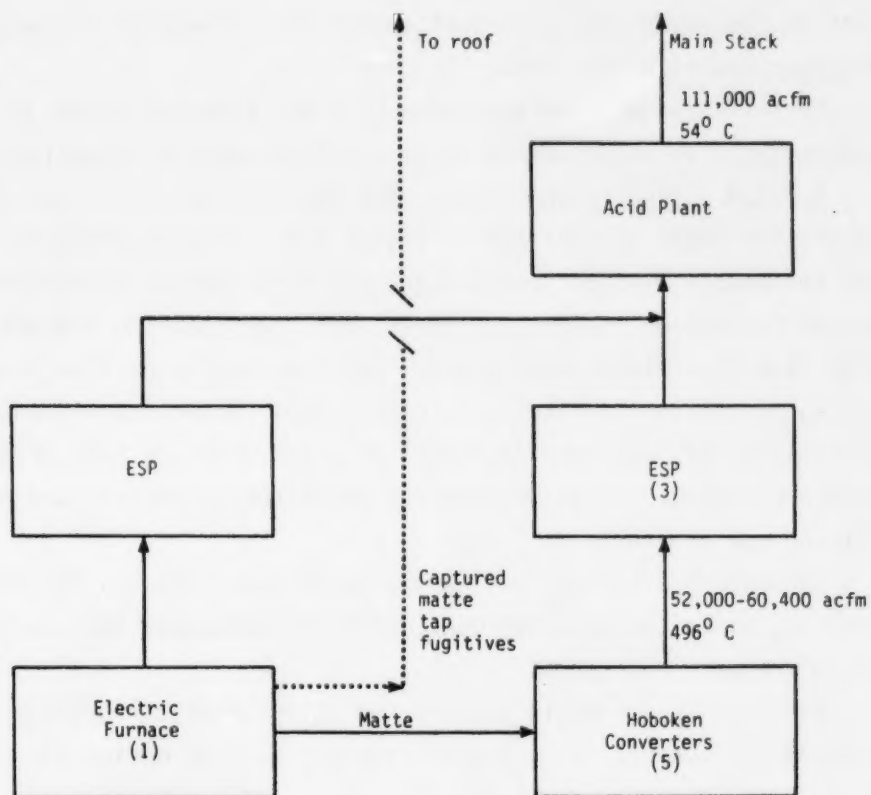


Figure 4-4. Inspiration-Miami Smelter Baseline Configuration

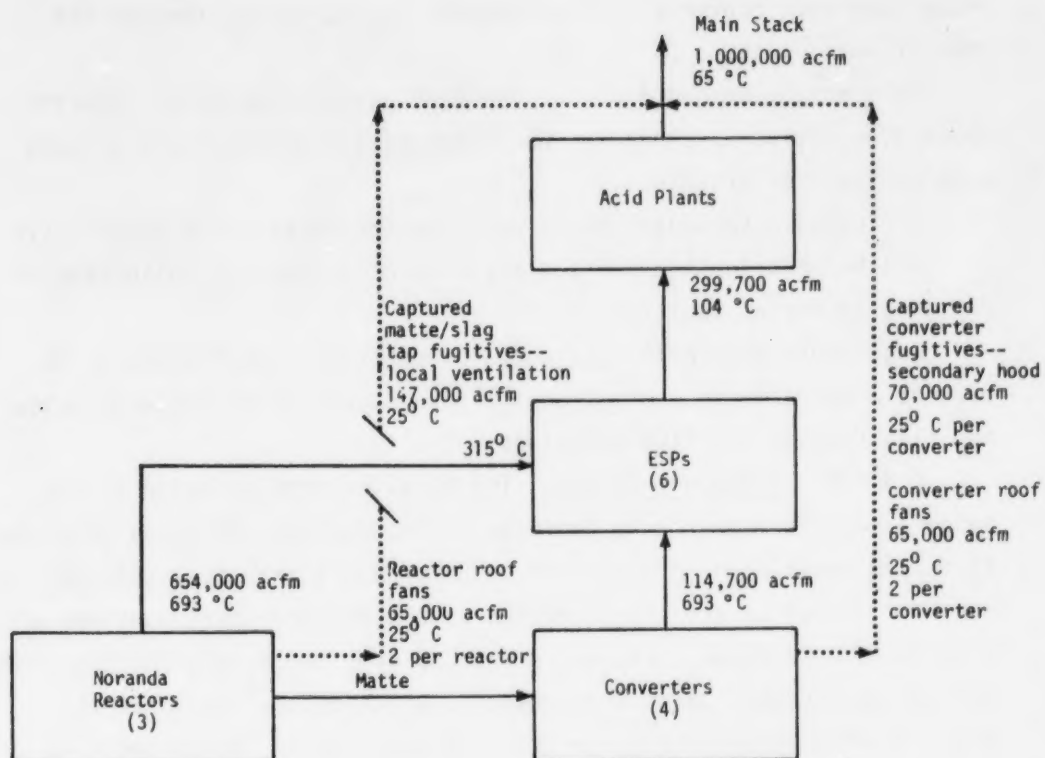


Figure 4-5. Kennecott-Garfield Smelter Baseline Configuration

escaped capture by the primary gas handling system or the capture ports near the hot metal transfer areas. The system consists of two 65,000 scfm axial I.D. fans mounted on the roof above each reactor vessel and each converter. The captured gas is vented through the smelter main stack.

No controls beyond the baseline configuration would be required under Alternative II since the baseline process controls are already best control for arsenic.

Air curtain secondary hoods would be installed under Alternative III, as would be an effective particulate control device for collection of captured converter fugitives.

Regulatory Alternative IV would necessitate installation of an effective particulate control device for collection of captured matte and slag tapping fugitive emissions.

4.3.2.6 Kennecott-Hayden. The baseline configuration of the Kennecott-Hayden smelter is depicted in Figure 4-6. Offgases from the fluid bed roaster go to a venturi scrubber and a tray-type scrubber in series. The gases are then combined with converter gases upstream of a sulfuric acid plant. Process emissions from the single reverberatory furnace are treated in an electrostatic precipitator (operated at 260°C, 500°F) before discharge from the main stack. Matte and slag tapping fugitive emissions are captured with local ventilation systems and discharged above the building roof without control. Converter fugitives are neither captured nor controlled.

Regulatory Alternative II would require no controls beyond those of the baseline configuration for the roaster and converter process offgas streams since these are already treated by best technology for arsenic control under baseline. The furnace electrostatic precipitator, which is "hot", is not considered best technology, but arsenic vapor pressure data (see Section 3.1.1.1) indicate that flue gas cooling would yield no additional emission reduction. Therefore, no additional controls for furnace process emissions would be required under Alternative II.

Alternative III would require the installation of air curtain secondary hoods on the converters, and a particulate control device for collection of captured converter fugitive emissions.

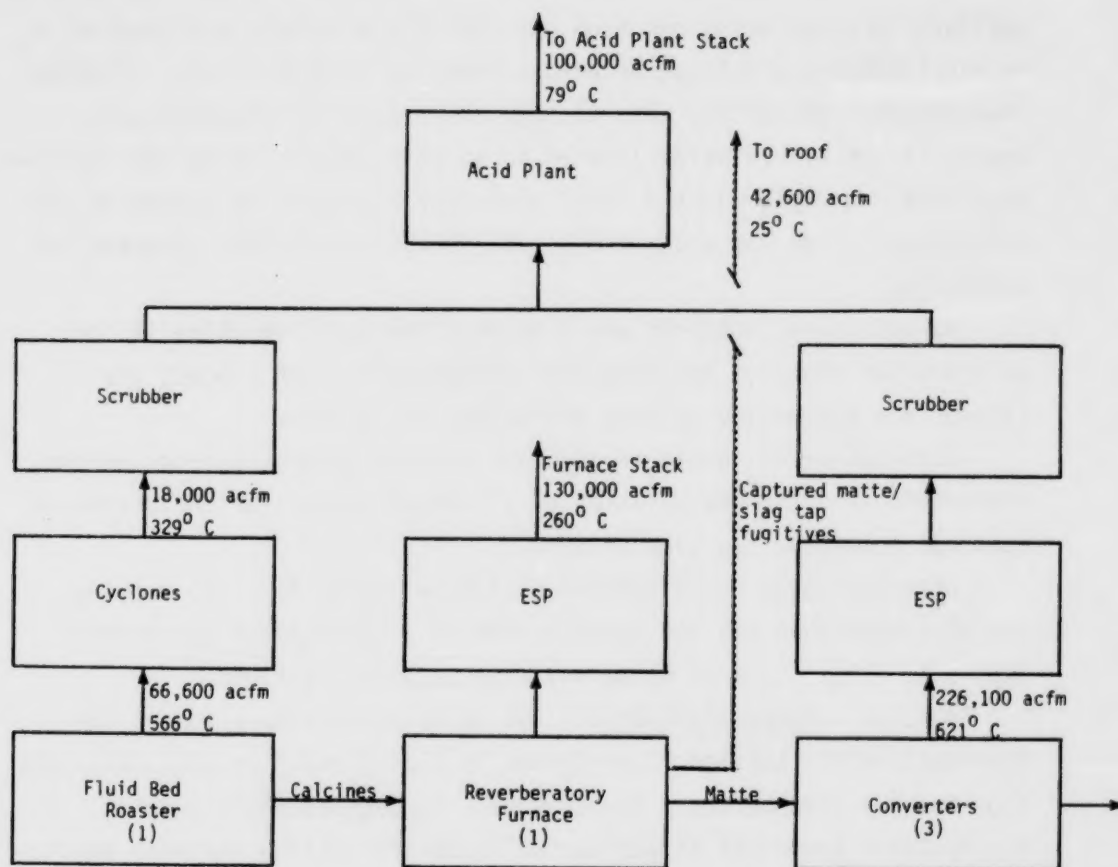


Figure 4-6. Kennecott-Hayden Smelter Baseline Configuration

Alternative IV would necessitate installation of a collection device for the captured matte and slag tapping fugitive emissions.

4.3.2.7 Kennecott-Hurley. Figure 4-7 shows the baseline configuration (after planned modernization, see Section 4.2.1) of the Kennecott-Hurley smelter. Process emissions from the INCO flash furnace are cleaned in an electrostatic precipitator before entering an acid plant. Offgases from the four converters pass through three parallel electrostatic precipitators before being treated in an acid plant. Matte tap fugitive emissions are captured by a local ventilation system and vented to the main stack. Slag tap and converter fugitives are neither captured nor controlled.

No additional controls would be required by Alternative II for this smelter since in the baseline configuration both process gas streams are controlled by best technology for arsenic.

Alternative III would require air curtain secondary hoods on the converters, and the installation of a control device for collection of captured converter fugitive emissions.

Alternative IV would require a capture system for slag tapping fugitive emissions and the installation of a particulate collection device to treat captured matte and slag tapping fugitives.

4.3.2.8 Kennecott-McGill. The baseline configuration of the Kennecott-McGill smelter is presented in Figure 4-8. Process emissions from the two reverberatory furnaces pass through an electrostatic precipitator (operated at 316°C, 600°F) before exiting the main stack. Converter offgases from any of the four units are treated in multiclones before being ducted to the stack. Matte and slag tap fugitives are captured by a local ventilation system and vented to the building roof. Fugitive emissions from the converters are neither captured nor controlled.

However, arsenic vapor pressure calculations (see Section 3.1.1.1) for the furnace offgases show that no additional arsenic emission reduction would result if the inlet temperature to the electrostatic precipitator were reduced to as low as 121°C (250°F). Therefore, Alternative II would have no effect on this gas stream. Similar calculations for the converter gas stream show that 57 percent arsenic collection would occur at 121°C (250°F). Alternative II therefore

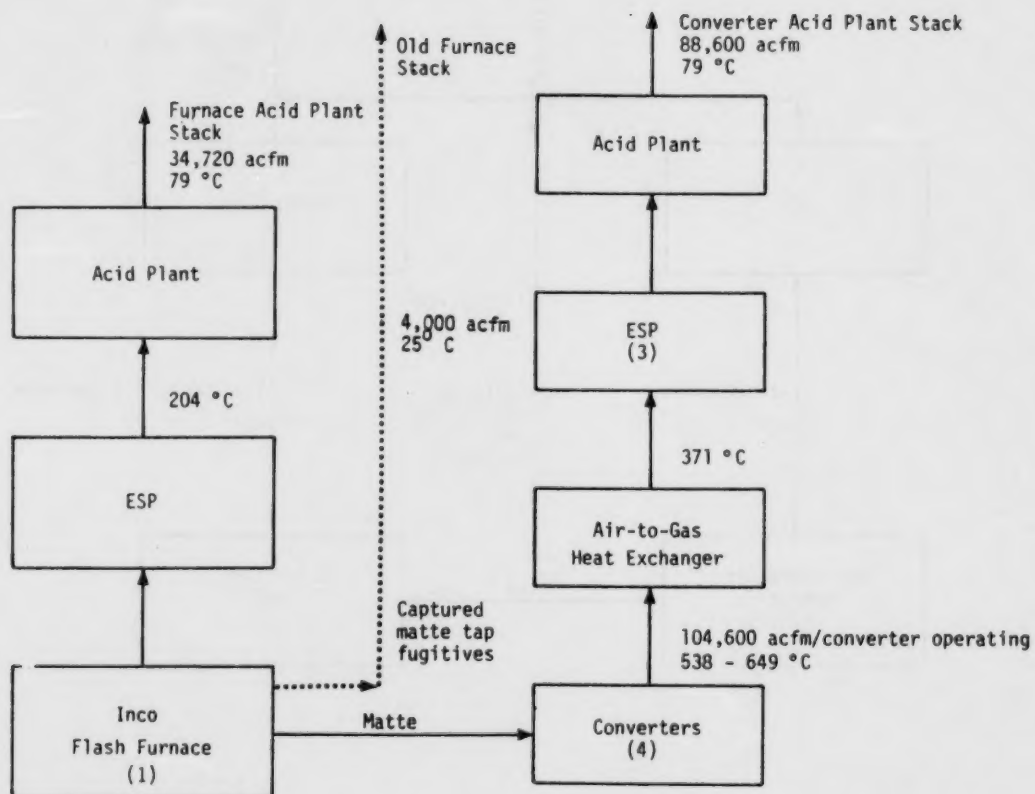


Figure 4-7. Kennecott-Hurley Smelter Baseline Configuration

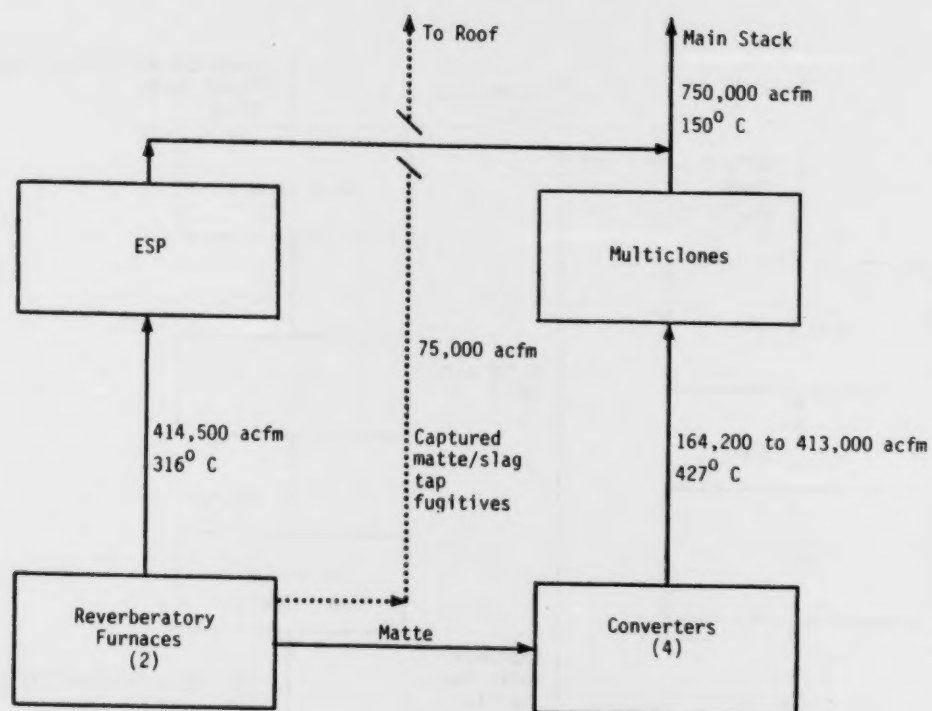


Figure 4-8. Kennecott-McGill Smelter Baseline Configuration

would require flue gas cooling upstream of an effective particulate control device for the converter process offgases.

Alternative III would require the installation of air curtain secondary hoods on the converters, and a control device for collection of captured converter fugitive emissions.

Alternative IV would necessitate installation of a control device for collection of captured matte and slag tapping emissions.

4.3.2.9 Magma-San Manuel. Figure 4-9 depicts the baseline configuration of the Magma smelter. Offgases from the three reverberatory furnaces pass through an electrostatic precipitator (operated at 260°C, 500°F) before discharge from the main stack. Process emissions from the six converters are also treated in an electrostatic precipitator, and then routed to an acid plant. Matte and slag tap fugitive emissions are captured and vented from the roof of the furnace building. Converter fugitives are neither captured nor controlled.

Since the baseline configuration reflects best control of arsenic in the converter process gas stream, no additional controls would be required under Regulatory Alternative II. Arsenic vapor pressure calculations (refer to Section 3.1.1.1) for the furnace gas stream indicate that no additional arsenic collection would be achieved by flue gas cooling to 121°C (250°F), therefore, no additional controls beyond baseline would be required under Alternative II.

Converter fugitive emissions would be captured by air curtain secondary hoods under Regulatory Alternative III. An effective control device would be required for collection of the captured emissions.

Alternative IV would cause the installation of a control device to collect the captured matte and slag tapping emissions.

4.3.2.10 Phelps Dodge-Ajo. The baseline configuration (after consent decree modification, see Section 4.2.1) of the Phelps Dodge-Ajo smelter is presented in Figure 4-10. Process emissions from the oxygen-sprinkle modified reverberatory furnace will pass through a hot electrostatic precipitator before being treated in the single acid plant. Offgases from the three converters pass through two electrostatic precipitators before entering the acid plant. Matte and slag tapping fugitive emissions are captured by localized ventilation and vented to the main stack. Converter fugitives are captured by a secondary hood system estimated to be 30 percent efficient and vented to the stack.

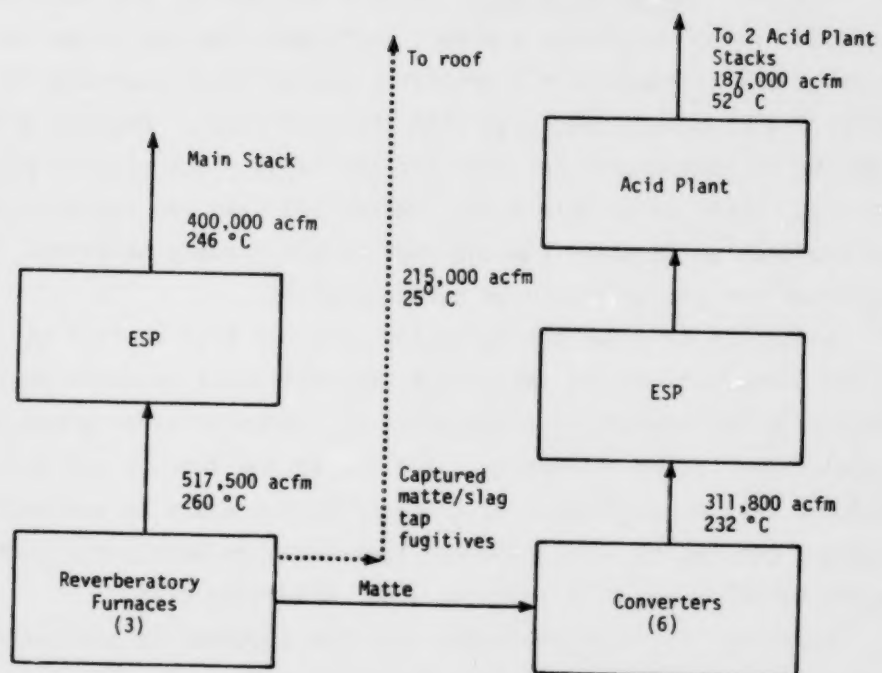


Figure 4-9. Magma-San Manuel Smelter Baseline Configuration

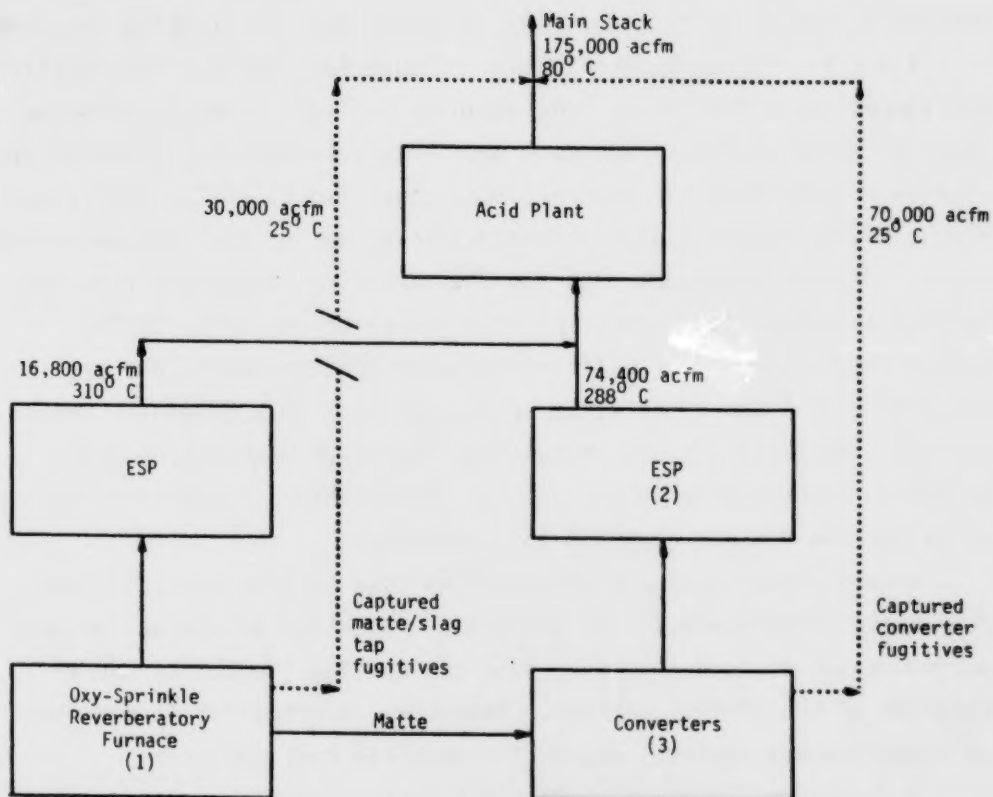


Figure 4-10. Phelps Dodge-Ajo Smelter Baseline Configuration

Alternative II would impose no process controls beyond those in the baseline configuration since they represent best technology for arsenic control.

Alternative III would require air curtain secondary hoods on converters, and the installation of a control device to collect the captured converter fugitives.

Alternative IV would necessitate installation of a particulate control device to collect the captured matte and slag tapping emissions.

4.3.2.11 Phelps Dodge-Douglas. Figure 4-11 depicts the baseline configuration of the Phelps Dodge-Douglas smelter. Process offgases from the 24 multi-hearth roasters and three reverberatory furnaces are cleaned in electrostatic precipitators (operated at 260°C, 500°F, and 232°C, 450°F, respectively) before discharge out of the roaster/reverb stack. Process emissions from the five existing converters also pass through an electrostatic precipitator (operated at 177°C, 350°F) before stack discharge. Calcine discharge fugitive emissions are captured by a local ventilation system and sent to a baghouse. Matte and slag tap fugitives are captured by localized ventilation and ducted to the converter electrostatic precipitator. Converter fugitive emissions are neither captured nor controlled.

Arsenic vapor pressure calculations (see Section 3.1.1.1) show that under Alternative II, no additional reduction in process arsenic emissions occurs as a result of flue gas cooling (to 121°C, 250°F) upstream of the control devices. Therefore, Alternative II requires no added process controls beyond the baseline configuration.

Alternative III would require air curtain secondary hoods on all converters along with installation of a control device to collect captured converter fugitive emissions.

Alternative IV would not affect calcine transfer fugitive emissions, since in the baseline configuration these emissions are controlled in a baghouse. Alternative IV would require installation of an additional control device for collection of captured matte and slag tapping fugitive emissions.

4.3.2.12 Phelps Dodge-Hidalgo. The baseline configuration of the Hidalgo smelter is shown in Figure 4-12. Offgases from the Outokumpu flash furnace are treated in three parallel electrostatic

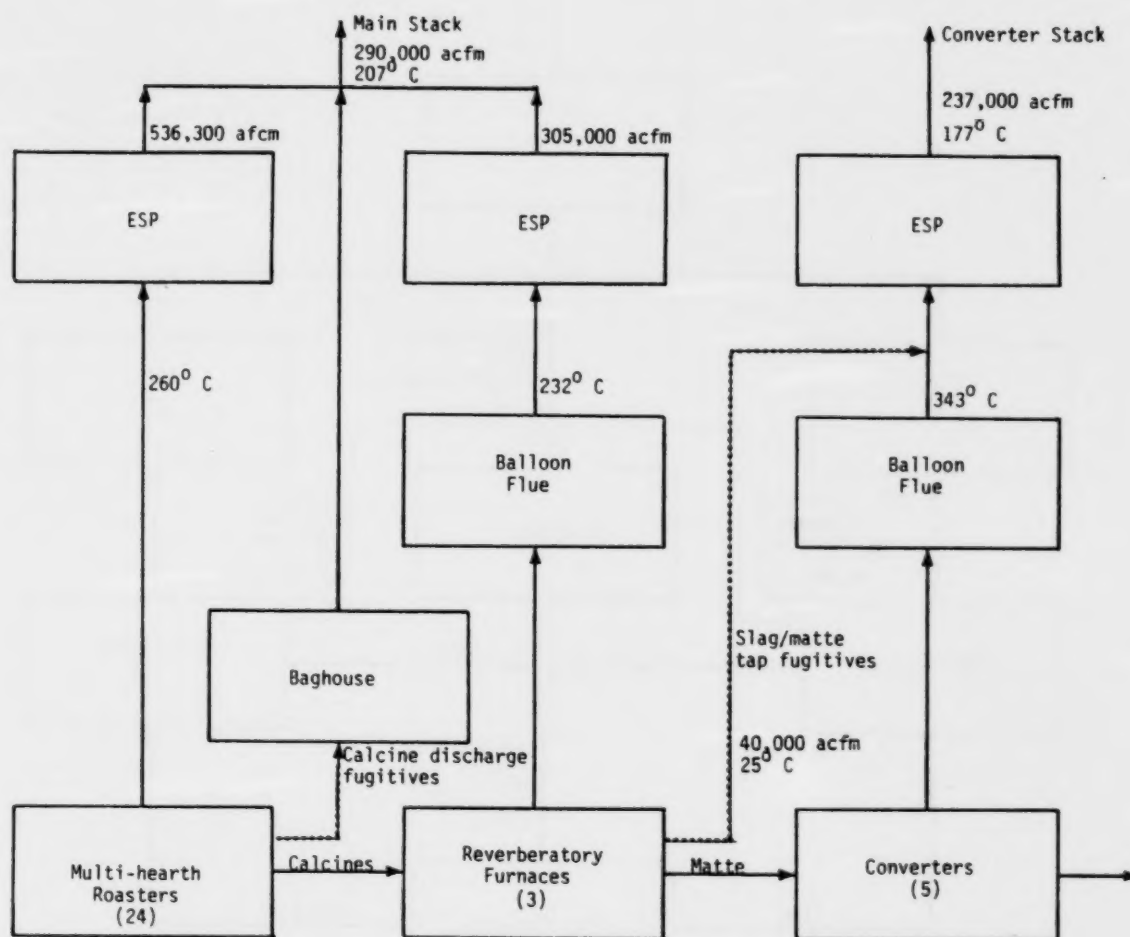


Figure 4-11. Phelps Dodge-Douglas Smelter Baseline Configuration

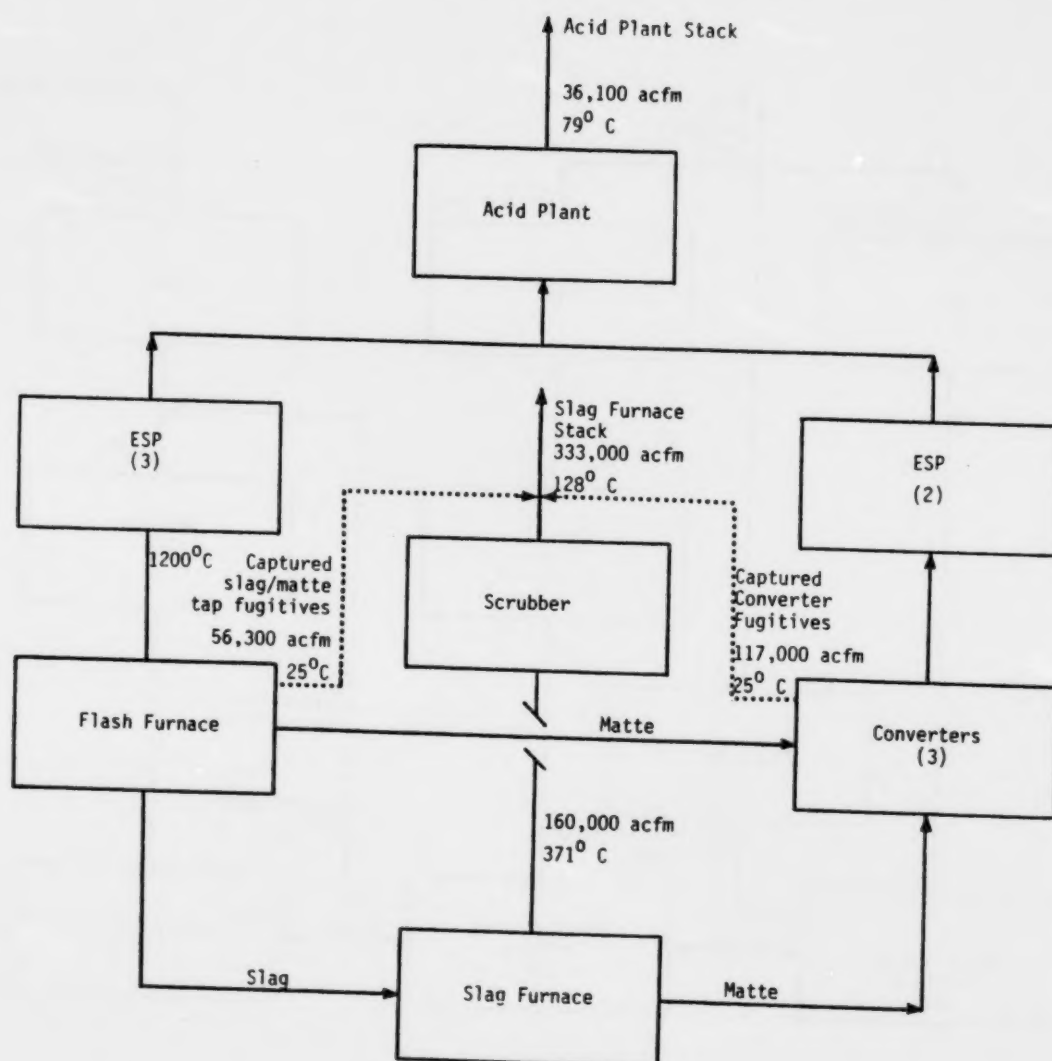


Figure 4-12. Phelps Dodge-Hidalgo Smelter Baseline Configuration

precipitators before being mixed with emissions from the three converters which have passed through two parallel electrostatic precipitators. Combined process offgases are then treated in either of two acid plants. Slag furnace process emissions are treated in a venturi scrubber and discharged from a separate stack. Matte and slag tap fugitive emissions are captured by local ventilation systems and vented to the slag furnace stack. Converter fugitives are captured by secondary hoods (estimated to be 30 percent efficient) and ducted to the slag furnace stack.

Alternative II would require no additional controls beyond the baseline configuration, since the baseline controls represent best technology for arsenic removal.

Alternative III would require air curtain secondary hoods on converters, and the installation of a control device to collect the captured converter fugitives.

Alternative IV would necessitate installation of a control device for collection of captured matte and slag tapping emissions.

4.3.2.13 Phelps Dodge-Morenci. Figure 4-13 presents the baseline configuration (after consent decree modification, see Section 4.2.1) of the Phelps Dodge-Morenci smelter. Offgases from the two oxygen sprinkle modified reverberatory furnaces will pass through two parallel electrostatic precipitators prior to treatment in an acid plant. Converter process emissions from the nine existing units pass through gas coolers and an electrostatic precipitator before entering an acid plant. Matte and slag tap fugitive emissions are captured by local ventilation systems and will be vented to the reverberatory furnace acid plant stack. Converter fugitives are captured by secondary hoods (estimated to be 30 percent efficient) and discharged from the converter acid plant stack.

Alternative II would not require additional controls beyond the baseline configuration, since process gas streams are already under best control for arsenic.

Air curtain secondary hoods would be required by Alternative III, along with installation of a control device for collection of captured converter fugitives.

Alternative IV would require the installation of a particulate control device for the collection of captured furnace fugitive emissions.

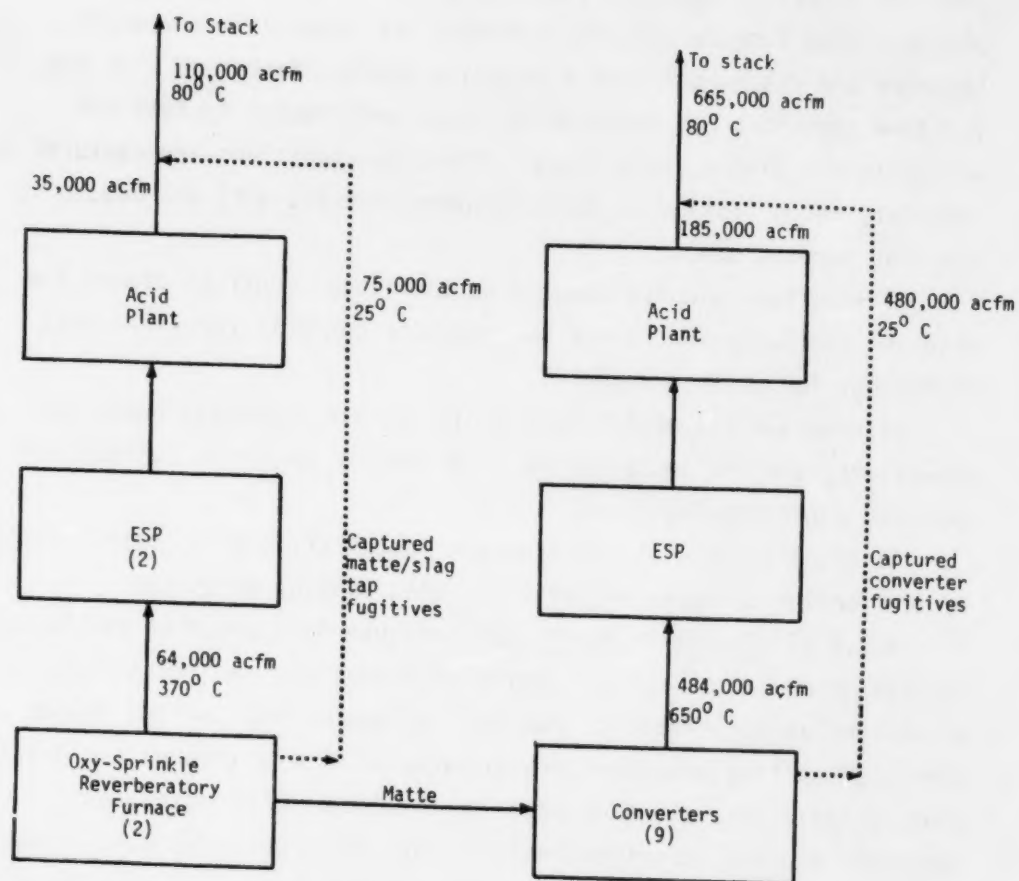


Figure 4-13. Phelps Dodge-Morenci Smelter Baseline Configuration

4.3.2.14 Copper Range-White Pine. The baseline configuration of the White Pine smelter is depicted in Figure 4-14. Process emissions from the two reverberatory furnaces pass through an electrostatic precipitator (operated at 190°C, 375°F) before discharge from the main stack. Converter offgases from the two units are vented directly to the stack. Matte and slag tap fugitive emissions are captured by local ventilation systems and vented to a stack on the building roof. Converter fugitives are neither captured nor controlled.

Arsenic vapor pressure calculations (see Section 3.1.1.1) show no additional arsenic removal resulting from application of cold (121°C, 250°F) particulate control devices on the process streams of the White Pine Smelter. Therefore, Alternative II does not require additional controls beyond the baseline configuration.

Alternative III would require air curtain secondary hoods on the converters, as well as installation of a particulate control device for collection of captured converter fugitive emissions.

Installation of a control device for the captured matte and slag tapping emissions would be required under Alternative IV.

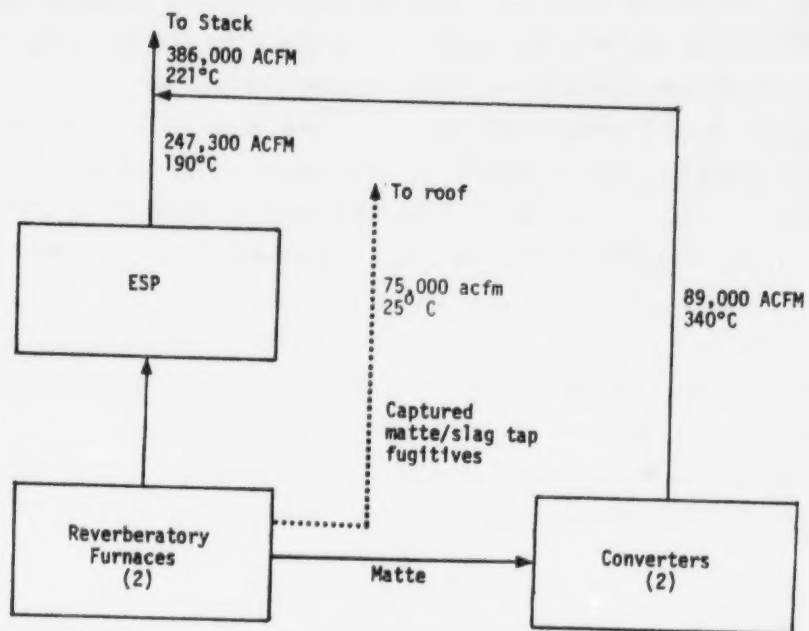


Figure 4-14. Copper Range-White Pine Smelter Baseline Configuration

4.4 REFERENCES

1. Environmental Protection Agency. Proposed Rules for Primary Nonferrous Smelter Orders. 44 FR 6284. January 31, 1979.
2. Environmental Protection Agency. Primary Nonferrous Smelter Orders; National Rules. 45 FR 123. June 24, 1980.
3. Telecon. Bill Gill, Texas Air Control Board with Scott Osbourn, Pacific Environmental Services. April 14, 1983. Discussed compliance status and applicable regulations for the ASARCO-El Paso smelter.
4. Telecon. Dave Chelgrin, Arizona Department of Health Services with Scott Osbourn, Pacific Environmental Services. April 14, 1983. Discussed compliance status and applicable regulations for copper smelters located in Arizona.
5. Correspondence from E.R. Flowers, Tennessee Division of Air Pollution Control, to M.G. Whaley, Pacific Environmental Services. June 8, 1983. Applicable regulations and compliance status for Tennessee Chemical Co. smelter.
6. Telecon. Monte Keller, Utah Department of Health with Scott Osbourn, Pacific Environmental Services. April 14, 1983. Discussed compliance status and applicable regulations for the Kennecott-Garfield smelter.
7. Telecon. David Duran, New Mexico Environmental Improvement Division with Scott Osbourn, Pacific Environmental Services. April 14, 1983. Discussed compliance status and applicable regulations for the Kennecott-Hurley and Phelps Dodge-Hidalgo smelter.
8. Telecon. Dick Serdoz, Nevada Division of Environmental Protection with Scott Osbourn, Pacific Environmental Services. April 14, 1983. Discussed compliance status and applicable regulations for the Kennecott-McGill smelter.
9. Telecon. Dennis Drake, Michigan Department of Natural Resources with Glenn Whaley, Pacific Environmental Services. June 7, 1983. Discussed compliance status and applicable regulations for the White Pine smelter.
10. U.S. Department of Labor, Occupational Safety and Health Administration. General Industry Standards (29 CFR 1910) and OSH 2206, Revised November 7, 1978.
11. Occupational Safety and Health Administration. Engineering Assessment and Proposed Compliance Plan for ASARCO-El Paso Copper Smelter. November 1982.

12. Occupational Safety and Health Administration. Engineering Assessment and Proposed Compliance Plan for ASARCO-Hayden Copper Smelter. October 1981.
13. Occupational Safety and Health Administration. Engineering Assessment and Proposed Compliance Plan for ASARCO-Tacoma Copper Smelter. January 1982.
14. Telecon. G. Whaley, Pacific Environmental Services, with C. Gordon, Occupational Safety and Health Administration. Status of Compliance Plans for Inorganic Arsenic Control at Primary Copper Smelters. April 20, 1983.
15. Environmental Protection Agency. Nonferrous Metals Manufacturing Point Source Category; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards. Federal Register, Vol. 48. February 17, 1983. p. 7032.
16. Environmental Protection Agency and Phelps Dodge Corporation. Consent Decree for Morenci and Ajo Copper Smelters. March 16, 1981.
17. Environmental Protection Agency and ASARCO, Incorporated. Consent Decree for Hayden Copper Smelter. April 13, 1981.
18. Kennecott Corporation. Compliance Schedule for Hurley (Chino) Smelter. March 28, 1983.

5.0 ENVIRONMENTAL IMPACTS

5.1 INTRODUCTION

The environmental impacts on air, energy consumption, solid wastes, and water associated with the regulatory alternatives for the control of arsenic emissions from the 14 low-arsenic throughput copper smelters are presented in this chapter. The purpose of this analysis is to determine the incremental change in air pollution, water pollution, solid waste, and energy impacts of the regulatory alternatives over the baseline control level for the low-arsenic throughput smelters nationwide.

This chapter first addresses the air pollution impacts of implementing each of the regulatory alternatives. Energy, solid waste, and water pollution impacts for the regulatory alternatives are addressed in Sections 5.3, 5.4, and 5.5, respectively.

5.2 AIR POLLUTION IMPACTS OF REGULATORY ALTERNATIVES

The air pollution impact associated with each of the regulatory alternatives considered for low-arsenic throughput copper smelters is presented in this section. Incremental and cumulative arsenic emission reductions by smelter and nationwide are discussed. The emission estimates for each regulatory alternative are obtained based on the application of capture and collection control systems selected in Section 4.3 as the bases for the regulatory alternatives.

5.2.1 Baseline Emissions

The baseline control level is represented by Regulatory Alternative I for all 14 low-arsenic throughput copper smelters. For 10 of the 14 smelters, the baseline level reflects existing control of arsenic emissions. The four remaining smelters are currently planning or undergoing modernization programs involving changes in processing and control equipment. For the purpose of defining baseline emissions,

these 4 plants are assumed to be in their modernized configurations as described in Section 4.2.

Baseline regulatory alternative arsenic emission rates are determined for each low-arsenic throughput smelter based on the arsenic material balances presented in Appendix F and the estimated capture and collection efficiencies of control equipment from Chapters 3 and 4. Baseline arsenic emission rates are presented in Table 5-1. This table shows both process and fugitive emission rates for each smelter. From Table 5-1, arsenic emission rates under Alternative I range from 0.09 kg/hr for both Kennecott-Hurley and Tennessee Chemical Co.-Copperhill to 52.1 kg/hr for Kennecott-McGill. The baseline arsenic emission rate nationwide is the sum of the arsenic emission rates for all 14 smelters. As shown in the table, the nationwide baseline inorganic arsenic emission rate is 85.8 kg/hr.

Nationwide annual arsenic emissions, shown in Table 5-2, are determined using the emission rates from Table 5-1 and assuming 8,600 hours of smelter operation per year. For Alternative I, nationwide annual inorganic arsenic emissions are 738 Mg/yr.

5.2.2 Arsenic Emission Reductions Under the Regulatory Alternatives

Regulatory Alternative II specifies effective controls for process emissions where additional arsenic removal is predicted. For this alternative, the Kennecott-McGill smelter would be the only smelter required to install new equipment. A new baghouse or cold electrostatic precipitator would need to be installed on the converters. From Table 5-1, arsenic emission rates under Alternative II range from 0.09 kg/hr for both Kennecott-Hurley and Tennessee Chemical Co.-Copperhill to 33.3 kg/hr for Kennecott-McGill. The nationwide inorganic arsenic emission rate under Alternative II is 66.8 kg/hr. From Table 5-2, nationwide annual emissions under Alternative II are 575 Mg/yr. This represents a 22 percent reduction in arsenic emissions nationwide from the baseline level.

Regulatory Alternative III specifies the application of effective converter fugitive inorganic arsenic emission controls. Effective controls for converter fugitive emissions include an air curtain secondary hood capture system followed by a fabric filter control device. From Table 5-1, arsenic emission rates under Alternative III

Table 5-1. ARSENIC EMISSIONS FROM LOW-ARSENIC THROUGHPUT COPPER SMELTERS
BY EMISSION SOURCE AND REGULATORY ALTERNATIVE

Smelter	Arsenic Emissions by Regulatory Alternative (kg/hr)											
	Alternative I			Alternative II			Alternative III			Alternative IV		
	Process	Fugitive	Total	Process	Fugitive	Total	Process	Fugitive	Total	Process	Fugitive	Total
ASARCO-EI Paso	1.5	4.0	5.5	1.5	4.0	5.5	1.5	1.8	3.3	1.5	4.0	5.5
ASARCO-Hayden	0.2	6.1	6.3	0.2	6.1	6.3	0.2	3.2	3.4	0.2	6.1	6.3
Tennessee Chemical Co. - Copperhill	0.0	0.09	0.09	0.0	0.09	0.09	0.0	0.02	0.02	0.0	0.07	0.07
Inspiration-Miami	0.04	0.4	0.4	0.04	0.4	0.4	0.04	0.2	0.2	0.04	0.3	0.3
Kennecott-Garfield	1.8	2.8	4.6	1.8	2.8	4.6	1.8	2.0	3.8	1.8	2.6	4.4
Kennecott-Hayden	3.2	0.9	4.1	3.2	0.9	4.1	3.2	0.2	3.4	3.2	0.8	4.0
Kennecott-Hurley	0.0005	0.09	0.09	0.0005	0.09	0.09	0.0005	0.04	0.04	0.0005	0.08	0.08
Kennecott-McGill	45.8	6.3	52.1	27.0	6.3	33.3	45.8	1.5	47.3	45.8	5.9	51.7
Magma-San Manuel	1.3	0.08	1.4	1.3	0.08	1.4	1.3	0.03	1.3	1.3	0.07	1.4
Phelps Dodge-Ajo	3.7	0.5	4.2	3.7	0.5	4.2	3.7	0.2	3.9	3.7	0.4	4.1
Phelps Dodge-Douglas	4.4	0.6	5.0	4.4	0.6	5.0	4.4	0.1	4.5	4.4	0.6	5.0
Phelps Dodge-Hidalgo	0.2	0.2	0.5	0.2	0.2	0.5	0.2	0.1	0.3	0.2	0.2	0.4
Phelps Dodge-Horncbl	0.1	1.0	1.1	0.1	1.0	1.1	0.1	0.3	0.4	0.1	0.9	1.0
Copper Range-White Pine	0.2	0.07	0.3	0.2	0.07	0.3	0.2	0.03	0.2	0.2	0.06	0.3
Nationwide Arsenic Emission Rate	62.5	23.1	85.8	43.7	23.1	66.8	62.5	9.6	72.1	62.5	22.0	84.5

Table 5-2. NATIONWIDE ANNUAL ARSENIC EMISSIONS BY
REGULATORY ALTERNATIVE AND EMISSION REDUCTIONS
FROM BASELINE

Regulatory Alternative	Arsenic Emissions (Mg/yr)	Arsenic Emission Reductions from Baseline	
		(Mg/yr)	(%)
Alternative I (Baseline)	738	--	--
Alternative II	575	163	22
Alternative III	620	118	16
Alternative IV	727	11	1.5

range from 0.02 kg/hr for Tennessee Chemical Co.-Copperhill to 47.3 kg/hr for Kennecott-McGill. The nationwide emission rate under Alternative III is 72.1 kg/hr. From Table 5-2, nationwide annual emissions under Alternative III are 620 Mg/yr. This represents a 16 percent reduction in arsenic emissions nationwide from the baseline level.

Regulatory Alternative IV specifies the installation of effective fugitive controls for matte and slag tapping operations. Effective control of fugitive emissions from these sources includes local ventilation hood capture followed by a fabric filter collection system. From Table 5-1, arsenic emission rates under Alternative IV range from 0.07 kg/hr for Tennessee Chemical Co.-Copperhill to 51.7 kg/hr for Kennecott-McGill. The nationwide inorganic arsenic emission rate under Alternative IV is 84.5 kg/hr. From Table 5-2, nationwide annual emissions under alternative IV are 727 Mg/yr. This represents a 1.5 percent reduction in inorganic arsenic emissions nationwide from the baseline level.

Regulatory Alternative V requires zero emissions of arsenic to the atmosphere from low arsenic throughput copper smelters. Under this alternative, air pollution, energy, and other environmental impacts would reduce to zero.

5.3 ENERGY IMPACTS OF THE REGULATORY ALTERNATIVES

Energy use associated with the baseline case was estimated assuming that low arsenic throughput copper smelters require 35×10^6 Btu (thermal) of energy per ton of copper produced.¹ The 14 low arsenic copper smelters have a total reported copper production capacity of 1.6×10^6 Mg/yr (1.8×10^6 tons/year).² Assuming a power plant efficiency of 35 percent, the total nationwide electrical energy requirement of low arsenic throughput copper smelters was estimated to be about 5×10^{10} kWh/yr.

Annual energy requirements for Regulatory Alternatives II through IV were estimated based on the energy requirements of additional control equipment specified for each regulatory alternative. For Alternative II, additional energy is required for control of process emissions from the converters at Kennecott-McGill. For Alternative III, additional energy is required for the capture and collection of converter fugitive emissions. For Alternative IV, additional energy is required

for the collection of fugitive emissions from matte and slag tapping operations.

Table 5-3 summarizes the nationwide incremental energy requirements of the regulatory alternatives over the baseline case for low arsenic throughput smelters. Incremental energy requirements, shown in this table, are 4.9×10^8 kWh for Alternative II, 1.8×10^8 kWh for Alternative III, and 9×10^6 kWh for Alternative IV. Under Alternative II, only the Kennecott-McGill smelter is required to install additional process pollution control equipment. Therefore, the incremental energy requirements for Alternative II reflect the additional electrical energy needed to operate emission control equipment at the Kennecott-McGill smelter. This additional requirement, 4.9×10^8 kWh, reflects fan and ESP electrical consumption plus the energy required to reheat the stack gases in order to maintain plume buoyancy. Thermal energy for reheat was calculated as electrical energy assuming a power plant efficiency of 0.35. The baseline energy requirements for the Kennecott-McGill smelter can be calculated assuming a baseline energy requirement of 35×10^6 Btu (thermal) of energy per ton of copper produced¹ and a total reported copper production capacity of 45,400 Mg/yr (50,000 tons/year).² The baseline electrical energy requirement for Kennecott-McGill is estimated to be 2×10^9 kWh. Compared to the baseline, the additional energy requirements of Alternative II represent an increase of 33 percent for the Kennecott-McGill smelter. The additional energy requirements of Alternatives III and IV for the 14 low arsenic throughput smelters are negligible when compared to the baseline area.

5.4 SOLID WASTE IMPACTS OF THE REGULATORY ALTERNATIVES

Arsenic-bearing dust is collected when smelting process particulate emissions are controlled with baghouses or electrostatic precipitators. Often, this dust contains recoverable copper or other salable materials. The collected dust is recycled to the process or reclaimed elsewhere. Thus, only a portion of the material collected by air pollution control equipment becomes solid wastes. Arsenic-containing materials are present in the acid plant waste. Acid plant waste is usually in the form of a slurry. State regulations require settling of this slurry in a concrete pit. The clarified slurry is transferred to a lined

Table 5-3. NATIONWIDE ANNUAL ENERGY REQUIREMENTS
BY REGULATORY ALTERNATIVE

Regulatory Alternative	Incremental Annual Energy Requirements from Baseline (10 ⁶ kWh/yr)
Alternative I (Baseline)	--
Alternative II	490 ^a
Alternative III	180
Alternative IV	9

^aRepresents the additional energy required by Kennecott-McGill for process control equipment and stack gas reheat.

lagoon for further settling. From the lagoon the materials may be dredged and recycled to the process.³

A conservative estimate of the amount of solid wastes generated nationwide under the baseline case can be made by assuming that 50 percent of the concentrate fed to the smelter becomes solid waste; 25 percent is sulfur which is removed from the process as SO_2 , and the remaining 25 percent becomes blister copper. Given a nationwide annual maximum concentrate feed rate of 6.4×10^6 Mg/yr,² solid wastes (including slag) generated nationwide by low arsenic smelters are approximately 3.2×10^6 Mg/yr.

The incremental quantity of solid waste generated nationwide for Regulatory Alternatives II through IV is shown in Table 5-4. Incremental solid waste impacts are estimated by assuming that all process and fugitive emissions collected under each alternative contain 1 percent arsenic. In comparison with the amount of solid waste generated by the smelter under the baseline case, the additional amounts of solid waste collected under Alternatives II through IV are negligible.

5.5 WATER POLLUTION IMPACTS OF THE REGULATORY ALTERNATIVES

The control systems for the regulatory alternatives are dry systems; consequently, no incremental increase in water discharges is anticipated. If scrubbers are used, increases in wastewater discharges result if the arsenic-containing dusts are disposed along with the acid plant slurry. Even if scrubbers are used, no adverse water pollution impact is anticipated. This is because the additional waste water discharges through use of scrubbers would be treated within existing smelter water pollution control systems installed to meet existing State and Federal regulations.

Table 5-4. NATIONWIDE ANNUAL SOLID WASTES GENERATED
BY REGULATORY ALTERNATIVE

Regulatory Alternative	Incremental Solid Wastes Generated Annually from Baseline (Mg/yr) ^a
Alternative I (Baseline)	--
Alternative II	16,300
Alternative III	11,800
Alternative IV	1,100

^a Assumes annual nationwide concentrate feed rate of 6.4×10^6 Mg concentrate/yr; 50 percent of concentrate becomes solid waste, and that all process and fugitive emissions collected under Alternatives II through IV contain 1 percent arsenic.

5.6 REFERENCES

1. Pitt, C.H., and M.E. Wadsworth. An Assessment of Energy Requirements in Proven and New Copper Processes. Prepared for the U.S. Department of Energy. Contract No. EM-78-S-07-1743. December 31, 1980. p. 9.
2. Preliminary Study of Sources of Inorganic Arsenic. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. Report No. EPA 450/5-82-005. August 1982. p. 21.
3. Calspan Corporation. Assessment of Industrial Hazardous Waste Practices in the Metals Smelting and Refining Industry. Volume II, Primary and Secondary Nonferrous Smelting and Refining. PB 276170. April 1971.

6.0 COSTS

This section presents capital and annualized costs of controlling (1) process arsenic emissions; and (2) fugitive arsenic emissions from matte and slag tapping and converter operations at low arsenic throughput copper smelters. These data are used to determine the cost of implementing the regulatory alternatives identified in Section 4. The control requirements of the regulatory alternatives for each smelter are presented in Table 6-1. As indicated in Section 4, roaster calcine discharge operations at the calcine charge smelters are effectively controlled for fugitive arsenic emissions and therefore are excluded from the cost analysis.

The capital cost includes all the cost items necessary to design, purchase, and install the particulate control system. The capital cost of a control system includes the purchase cost of the control device, auxiliaries such as exhaust fans, motors, ductwork, and stack; direct installation charges including foundation and other direct costs such as electrical, instrumentation and controls; and indirect costs for engineering services, taxes, contractors fees, and contingency. All costs are in December 1982 dollars.

The annualized cost of a control system is the annual cost to the individual plant to own and operate that control system. The annualized cost includes direct operating costs such as utilities, maintenance, operating labor, and indirect operating costs or capital-related charges such as depreciation, interest, administrative overhead, property taxes, and insurance.

While actual costs experienced by individual plants can vary, the following values have been selected as typical and provide a reasonable estimate of the annualized costs of each control system:

Table 6-1. REGULATORY ALTERNATIVE CONTROL REQUIREMENTS

Alternative	Control Requirement
I (Baseline case)	Existing process and fugitive controls on roasters, smelting furnaces and converters. Also included are those controls planned or agreed to be installed prior to 1987.
II	Effective process controls and existing fugitive controls. Effective process controls include evaporative cooling followed by either an existing or new ESP or fabric filter collector for particulate matter emissions.
III	Existing process controls and effective fugitive controls for converters. Effective fugitive controls for converters include air curtain secondary hoods for capture followed by fabric filters for collection.
IV	Existing process controls and effective fugitive controls for matte tapping and slag tapping operations. Effective fugitive controls for matte tapping and slag tapping operations include local ventilation for capture followed by fabric filters for collection.

Direct annualized cost items

- Operating labor at \$11.53 per hour¹ and supervision labor at 15 percent of operating labor expense.
- Maintenance labor at \$11.53 per hour¹ and supervision labor at 20 percent of maintenance labor expense.
- Maintenance material at 100 percent of maintenance labor expense.
- Electricity at 5.9 cents per kilowatt hour.²
- Water at 8¢/m³ (\$0.30/1,000 gallons).³
- Natural gas at \$5.67/GJ (\$5.98/million Btu)

Indirect annualized cost items

- Payroll overhead at 60 percent of payroll.
- Operating supplies at 20 percent of total maintenance cost.
- Administrative overhead at 40 percent of total operating and maintenance labor and operating supplies.
- Taxes and insurance at 2 percent of total capital cost.³
- Capital recovery at 20 year life for ESP's and fabric filters, 10 year life for reheat equipment, and 10 percent interest rate.

A detailed cost analysis for the alternate control systems is presented in the following sections.

6.1 BASELINE CONTROLS

This section presents the estimated costs of baseline controls on process and fugitive emission sources. The baseline controls are defined as the existing process and fugitive controls planned or agreed to be installed before 1987. Baseline controls have no additional costs associated with them and therefore are excluded from the cost analysis. Some smelters are replacing or planning to replace existing smelting furnaces with a new smelting technology which generates SO₂ emissions in concentrations suitable for collection in a sulfuric acid plant. Sulfuric acid plants remove arsenic emissions contained in the process offgases treated in their gas precleaning and conditioning

equipment. For these smelters the baseline control cost includes the total cost of the new smelting technology, sulfuric acid plant, and any additional agreed upon controls. Table 6-2 lists the smelters for which agreements exist and presents the control equipment to be installed under each agreement.

6.1.1 Baseline Costs

Table 6-3 presents the estimated capital and annualized costs for the add-on equipment listed in Table 6-2. Capital and annualized costs for new smelting technologies were based on cost estimates contained in a draft report prepared for EPA.⁴ The report presents cost estimates in mid-1981 dollars for retrofitting INCO flash and oxygen sprinkle/oxygen fuel smelting technologies at existing smelters of varying capacity. The capital cost estimates were obtained by adjusting the cost data reported in the referenced report to represent the production capacity at a subject smelter and adjusting the resultant cost estimates upward to reflect December 1982 dollars. The annualized cost estimates were obtained by adjusting the reported data to be consistent with the annual operating cost bases presented above.

6.2 PROCESS CONTROLS

This section presents the estimated costs of applying effective controls on process emission sources. As discussed in Section 4 and presented in Table 6-1, effective process controls are defined as control systems containing evaporative cooling followed by an ESP for collection of process particulate matter emissions. As indicated in Section 4, by applying effective add-on process controls, additional arsenic emission reduction over baseline can be achieved only for converters at the Kennecott-McGill smelter. Therefore, the process control cost analysis in this section will be limited to developing cost estimates for the control of process emissions from converters at the Kennecott-McGill smelter.

6.2.1 Process Control Costs

Capital and annualized costs were estimated for an add-on evaporative cooler and ESP for the existing converter process emissions control system at the Kennecott-McGill smelter. Currently, the converter

Table 6-2. EQUIPMENT CONSIDERED IN BASELINE COST ANALYSIS

Smelter	Add-on equipment
1. ASARCO - El Paso	Fugitive emission capture system on smelter slag tapping operation.
2. ASARCO - Hayden	INCO smelting technology in place of the existing conventional roaster/reverberatory smelting process. Local ventilation for capture of fugitive emissions from the new smelter matte tapping and slag tapping operations and an existing ESP system for collection of captured emissions. ^a A sulfuric acid plant for process emissions.
3. Kennecott - Hurley ^b	INCO smelting technology in place of the existing conventional reverberatory smelting process. A sulfuric acid plant for process emissions from the new smelter.
4. Phelps Dodge - Ajo	Oxygen sprinkle/oxygen fuel smelting in place of the existing conventional reverberatory smelting process. A sulfuric acid plant for process emissions from the modified smelter.
5. Phelps Dodge - Morenci	Oxygen sprinkle/oxygen fuel smelting in place of the existing conventional reverberatory smelting process. A sulfuric acid plant for process emissions from the modified smelter.

^aSince an existing ESP will be used for the collection of captured emissions, the baseline cost analysis includes only an annual operating cost for the collection system.

^bNo formal agreement has been made between Kennecott Copper Company and EPA or any other agency regarding installation of the add-on control equipment listed.

Table 6.3. ESTIMATED CAPITAL AND ANNUALIZED COSTS OF
BASELINE CONTROLS FOR PRIMARY COPPER SMELTERS
(December 1982 dollars)

Smelter	Capital cost, \$1,000	Annualized cost, \$1,000
1. ASARCO - El Paso	46	40
2. ASARCO - Hayden	75,606	24,698
3. Kennecott - Hurley	54,044	17,111
4. Phelps Dodge - Ajo	51,067	16,356
5. Phelps Dodge - Morenci	92,294	30,815

offgases are treated in multi-cyclones and vented through a stack to the atmosphere. The design parameters used to calculate add-on control system costs are summarized in Table 6-4. No stack was included in the system with the assumption that the existing stack will be used to vent the offgases from add-on controls.

Methodology for Estimating Capital and Annualized Costs - Capital and annualized costs were developed for the evaporative cooler and ESP system by estimating capital costs separately for the evaporative cooler, ESP, fan, ductwork, and reheat and annualized costs for the entire system.

The capital costs for the evaporative cooler, ESP, and fan were based on data contained in a report prepared for EPA by the Industrial Gas Cleaning Institute (IGCI).⁵ The report presented estimates of equipment purchase and total capital costs for evaporative cooler and ESP systems for treating offgases from reverberatory furnaces at two smelters. These estimates were prepared by several ESP manufacturers in fourth quarter 1977 dollars. Using these reported cost data, a mathematical expression was developed to relate the reported purchase costs for evaporative cooler, ESP, and fan to gas flow rate. To this purchase cost expression, the following factors were applied to obtain a mathematical expression relating total capital cost in December 1982 dollars to gas flow rate: 175 percent to obtain total capital cost from purchase cost, 120 percent for an assumed 20 percent retrofit cost, and a 1.54 escalation factor to convert the costs in fourth quarter 1977 dollars to December 1982 dollars. The capital cost factor of 175 percent was obtained based on cost data in the IGCI report.⁵ The escalation factor of 1.54 was obtained by using the Chemical Engineering Plant cost index (December 1982 = 314.3). The resultant mathematical expressions relating equipment purchase cost (C_1) and capital cost (C_2) to gas flow rate are as follows:

$$\begin{aligned} C_1 &= \text{Purchase cost of evaporative cooler } (C_{1x}) + \text{Purchase} \\ &\quad \text{cost of ESP } (C_{1y}) + \text{Purchase cost of fan* } (C_{1z}) \\ &= 4,083(Q_1)^{0.91} + 16,663 (Q_2)^{0.89} + 1,093 (Q_1)^{0.96} \end{aligned}$$

*Fan is located on the hot side of the gas stream.

Table 6-4. DESIGN PARAMETERS FOR ADD-ON PROCESS
PARTICULATE MATTER CONTROL FOR CONVERTERS
AT KENNECOTT-MCGILL

Parameter	Value	
System description	A fan, an evaporative cooler, and a dry electrostatic precipitator	
<u>Evaporative cooler</u>		
Offgas at the inlet:		
Flow rate, m ³ /s (acfm)	197	(418,300)
Temperature, °C (°F)	232	(450)
Arsenic content, g/s (lb/min)	9.16	(1.21)
g/m ³ (gr/acf)	0.05	(0.02)
Water, content, % of total volume	4 ^a	
Water consumption, m ³ /h (gpm)	39	170
<u>Electrostatic precipitator</u>		
Offgas at the inlet ^b :		
Flow rate, m ³ /s (acfm)	154	(326,400)
Temperature, °C (°F)	120	(250)
Arsenic content, g/s (lb/min)	9.16	(1.21) ^c
g/m ³ (gr/acf)	0.06	(0.026)
Water content, % of total volume	8	
Migration velocity, cm/s (ft/min)	3.96	(7.8) ^d
Specific collection area, m ² per m ³ /s (ft ² /1,000 acfm)	103.2	(524) ^d
Power consumption, kw/m ² (kw/ft ²) of collection area	0.016	(0.0015)
Offgas at the outlet:		
Arsenic content, g/s (lb/min)	4.93	(0.65) ^e
g/m ³ (gr/acf)	0.032	(0.014) ^e
<u>Fan</u>		
Location		
Pressure drop, kPa (in. water)	Hot side of cooling system ^f	
Power consumption, kw (hp)	1	(4)
	615	(825)
<u>Reheat</u>		
Reheat temperature increase, °C (°F)	112	(200)
Capacity, GJ (million Btu/hr)	71	(67)

^a Assumed based on test data for converters at several other smelters.

^b Same as at the outlet of evaporative cooler.

^c The arsenic loading at the ESP inlet may be lower than that at the evaporative cooler inlet.

^d Quoted by ESP manufacturers for reverberatory furnaces in the IGC report.

^e Calculated using the arsenic saturation value of 0.0302 g/m³ (0.0132 gr/acf) at 120°C (250°F) and 96 percent efficiency for the add-on ESP system.

^f Downstream of the existing multicyclones and upstream of the add-on evaporative cooler.

where Q_1 = Actual flow rate at the inlet of add-on evaporative cooler, m^3/s , and

Q_2 = Actual flow rate at the inlet of add-on ESP, m^3/s at 120°C

C_2 = Capital cost of evaporative cooler and ESP

$$\begin{aligned} &= 1.54 \times 1.2 \times 1.75 (C_{1x} + C_{1y} + C_{1z}) \\ &= 3,234 [4,083 (Q_1)^{0.91} + 16,663 (Q_2)^{0.89} + 1,093 (Q_1)^{0.96}] \\ &= 3,535 [3.74 (Q_1)^{0.91} + 15.25 (Q_2)^{0.89} + Q_1^{0.96}] \end{aligned}$$

Ductwork costs were estimated based on an assumed total of 305 m (1,000 ft) of duct from the existing equipment outlet to the inlet of add-on control system (i.e., at the inlet to fan) and a return duct from the system outlet to the existing equipment. The ductwork cost (C_3) based on the total duct weight and a unit cost per weight of \$11,355/Mg (\$10,300/ton) was \$2,008,500. The unit cost of ductwork assumes that an additional 40 percent of the total ductwork weight is needed for support structures.

The capital cost for reheat equipment was based on data contained in a report prepared by EPA.⁶ The report presents capital cost estimates in fourth quarter 1977 dollars for reheat equipment of different capacity. The reported costs were escalated to December 1982 dollars using the Chemical Engineering Plant Cost Index (December 1982 = 314.3). A mathematical expression was developed to relate capital costs (C_4) in December 1982 dollars to gas flow rate. The resultant expression is:

$$C_4 = 1.54 [55,466 (Q_3)^{0.59}] = 85,418 (Q_3)^{0.59}$$

where Q_3 = Reheat capacity, GJ/h

The total capital cost (C) in December 1982 dollars for the evaporative cooler and ESP system is the summation of capital costs for the evaporative cooler, ESP, and fan (C_2), ductwork (C_3), and reheat equipment (C_4).

$$\begin{aligned}
C &= C_2 + C_3 + C_4 \\
&= 3,535 [3.74 (Q_1)^{0.91} + 15.25 (Q_2)^{0.89} + (Q_1)^{0.96}] \\
&= 2,008,500 + 85,418 (Q_3)^{0.59} \\
&= 3,535 [3.74 (Q_1)^{0.91} + 15.25 (Q_2)^{0.89} + (Q_1)^{0.96} \\
&\quad + 568.2 + 24.16 (Q_3)^{0.59}]
\end{aligned}$$

The estimated capital cost for an add-on evaporative cooler and ESP system located upstream from existing converter process controls at the Kennecott-McGill smelter is \$10,017,800. This cost was calculated using the gas parameters listed in Table 6-4 and the above mathematical expression.

Annualized costs were calculated based on operating parameters listed earlier and the following requirements:

- 2 manhours/shift operating labor and 1 manhour/shift maintenance labor.
- Pressure drop of 1.0 kPa (4 in. water) across evaporative cooler and ESP.
- Electricity for ESP at 0.0015 kW/ft² of ESP plate area.
- Miscellaneous electricity costs at 10 percent.

Table 6-5 presents an estimate of annualized cost for add-on process emission controls on converters at the Kennecott, McGill smelter.

6.3 FUGITIVE CONTROLS

This section presents the estimated costs of applying effective controls on fugitive emission sources at low arsenic throughput primary copper smelters.

6.3.1 Converter Controls

Fugitive emission control equipment selected for analysis for converter operations includes an air curtain secondary hood capture and fabric filter collection system. As noted in Section 4, five of the smelters currently have some form of converter secondary hooding in place. One smelter, ASARCO-El Paso, has a building evacuation

Table 6-5. ESTIMATED ANNUALIZED COST OF ADD-ON PROCESS
 PARTICULATE MATTER CONTROL SYSTEM FOR CONVERTERS
 AT KENNECOTT-McGILL
 (December 1982 dollars)

Item	Cost,\$
<u>Direct costs</u>	
Operating labor	28,600
Maintenance labor	15,000
Maintenance material	15,000
Utilities:	
Electricity ^a	312,400
Natural gas for reheat	2,252,500
Water	31,000
Total direct	2,654,500
<u>Indirect costs</u>	
Payroll overhead	26,200
Operating supplies	3,000
Administrative overhead	18,600
Taxes and insurance	200,300
Capital recovery:	
Evaporative cooler and ESP	1,053,000
Reheat equipment	171,800
Total indirect	1,472,900
Total	4,127,400

^a\$130,200 is ESP power requirement.

system which includes a fabric filter for emission collection. The five smelters with converter secondary hooding are ASARCO-Hayden, Kennecott-Garfield, Phelps Dodge-Ajo, -Morenci, and -Hidalgo.

6.3.1.1 Converter Control Costs - Capital and annualized costs were estimated for the installation of air curtain secondary hood capture and fabric filter collection systems on converters at all smelters. For smelters without existing fugitive controls on converters, the cost estimates include the total cost for installation of air curtain secondary hoods and fabric filters. However, for those smelters with some form of converter fugitive emission controls presently in place or required under an EPA consent decree, the cost estimates include only the incremental cost needed to upgrade the existing or future control systems to an air curtain secondary hood capture system equipped with an effective collection device.

The capital costs were developed by estimating costs for air curtain secondary hood capture equipment and fabric filter collection equipment for each smelter. The annualized costs were developed by estimating costs for the total capture and collection system at each smelter.

Capital costs for air curtain secondary hoods - Design parameters for air curtain secondary hood capture systems at each smelter are summarized in Table 6-6. Data on the number of existing and operating converters are based on the information obtained from individual companies and Reference 7. Exhaust fan capacities were developed using the design rates obtained from ASARCO and discussed in Section 3 for the air curtain secondary hood capture systems for converters at the Tacoma smelter. The following flow rates were used for each converter: $33 \text{ m}^3/\text{s}$ (70,000 acfm) during blowing and holding and $57 \text{ m}^3/\text{s}$ (120,000 cfm) during charging and skimming. Air curtain flow rates used were $5.2 \text{ m}^3/\text{s}$ (11,000 acfm) during blowing and $8.5 \text{ m}^3/\text{s}$ (18,000 acfm) during charging and skimming.

The following ductwork requirements were estimated for the smelters with no existing converter controls: for the first converter at each smelter 54 m (178 ft) of 1.5 m (60 in.) diameter duct was assumed to be needed to reach the main exhaust fan. An additional 19.8 m (65 ft)

Table 6-6. DESIGN PARAMETERS FOR AIR CURTAIN SECONDARY HOOD CAPTURE SYSTEM FOR PRIMARY COPPER SMELTERS

Smelter	No. of converters		Fan capacity, m ³ /s (acfm)	Flue system dimensions ^d
	total existing ^a	total operating ^b		
1. ASARCO - El Paso ^e	3	1R0, 1R1, 1SB	109 (230,000)	31 m (100 ft) long 1.5 m (60 in.) duct
2. ASARCO - Hayden ^f	5	1R0, 1R1, 1H	142 (300,000)	
3. Tennessee Chemical Co. - Copperhill	2	1R0	66 (140,000)	128 m (420 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 1.7 m (67 in.) duct
4. Inspiration - Miami	5	1R0, 1R1, 1H	142 (300,000)	469 m (1,540 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.5 m (98 in.) duct
5. Kennecott - Garfield ^f	4	1R0, 1R1, 1H	142 (300,000)	223 m (730 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.2 m (86 in.) duct
6. Kennecott - Hayden	3	1R0, 1R1, 1SB	109 (230,000)	335 m (1,100 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.5 m (98 in.) duct
7. Kennecott - Hurley	4	1R0, 1R1, 1H	142 (300,000)	335 m (1,100 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.5 m (98 in.) duct
8. Kennecott - McGill	4	1R0, 1R1, 1H	142 (300,000)	623 m (2,043 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 3 m (119 in.) duct
9. Nagma - San Manuel	6	2R0, 2R1	208 (440,000)	223 m (730 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.2 m (86 in.) duct
10. Phelps Dodge - Ajo ^g	3	1R0, 1R1, 1SB	109 (230,000)	469 m (1,540 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.2 m (86 in.) duct
11. Phelps Dodge - Douglas	5	1R0, 1R1, 1H	142 (300,000)	223 m (730 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.2 m (86 in.) duct
12. Phelps Dodge - Hidalgo ^g	3	1R0, 1R1, 1SB	109 (230,000)	223 m (730 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 2.2 m (86 in.) duct
13. Phelps Dodge - Morenci ^f	9	2R0, 2R1	208 (440,000)	
14. Copper Range - White Pine	2	1R0	66 (140,000)	128 m (420 ft) long 1.5 m (60 in.) duct and 91 m (300 ft) long 1.7 m (67 in.) duct

^aEach existing smelter will be equipped with an air curtain secondary hood capture system. Each air curtain will have a separate fan designed at 6.5 m³/s (18,000 acfm) at a pressure of 7.5 kPa (30 in. H₂O).

^bR0: Roll-out, R1: Roll-in, SB: Standby, and H: Holding.

^cFan capacities are based on operating converters only. Assumed exhaust rate from a converter in roll-out mode (i.e., during charging and skimming) is 57 m³/s (120,000 acfm) and from a converter in roll-in mode (i.e., during blowing and holding) is 33 m³/s (70,000 acfm).

^dDuct lengths used are: 54 m (178 ft) long 1.5 m (60 in.) diameter duct per system, 19.8 m (65 ft) long 1.5 m (60 in.) diameter duct for each additional system, and 91 m (300 ft) long common duct downstream of the fan. Example case Kennecott, Hayden: length of 1.5 m (60 in.) diameter duct is $3 \times 54 + (1) \times 19.8 + (2) \times 19.8 = 223$ m.

^eCurrently, the converter fugitive emissions are captured in a building evacuation system, and a duct exists to vent the captured emissions to fabric filter collection equipment. The existing duct is assumed to be utilized to vent the captured gases from the air curtain secondary hood. New 31 m (100 ft) ducting is sufficient to move the captured gases to the existing duct.

^fCurrently, the converter fugitive emissions are captured in a secondary hood and a duct exists to vent the captured gases to a stack. The existing duct is assumed to be utilized to vent the captured gases from the air curtain secondary hood. No new ducting or fans are required.

^gCurrently, the converter fugitive emissions are captured in a secondary hood and a duct exists to vent the captured gases to a stack. However, the existing system is smaller than the air curtain secondary hood capacity. Therefore, none of the existing equipment is assumed to be utilized.

of 1.5 m (60 in.) diameter duct is required for each subsequent capture system after the first one (i.e., 54 m duct for the first converter, 54 m + 19.8 m duct for the second converter, 54 m + 2 x 19.8 m for the third converter and 54 m + 3 x 19.8 m for the fourth converter). A 91 m (300 ft) common duct was used for venting gases from the main fan to the particulate collection device. The common duct diameters vary for each smelter based on exhaust fan capacity.

For the ASARCO-El Paso, -Hayden, Kennecott-Garfield, and Phelps Dodge-Morenci smelters with some form of existing converter controls in place, it was assumed the existing ductwork and fans were salvageable and could be incorporated in the new air curtain secondary hood system. A new 31 m (100 ft) of 1.5 m (60 in.) diameter ductwork was assumed to be required to move the captured gases from the new system to the existing ductwork at the ASARCO-El Paso smelter. No new ductwork was assumed to be required at the other smelters. At the Phelps Dodge-Ajo and -Hidalgo smelters, the existing converter control system capacity is smaller than the new air curtain secondary hood system. Therefore, none of the existing equipment was assumed to be salvageable. New ductwork costs were estimated for these smelters in the same manner as for the smelters with no existing converter controls.

Table 6-7 presents estimated capital costs for air curtain secondary hoods for each low arsenic throughput smelter. These cost estimates were calculated using the cost data provided to EPA by ASARCO.⁸ The ASARCO cost data contained January 1982 cost estimates for installing air curtain secondary hood capture equipment on three converters at the Tacoma smelter. The direct capital costs reported were based on actual estimates and indirect capital costs were based on percentages of the estimated equipment cost. These cost data were updated to December 1982 dollars and used to estimate the costs for installation of an air curtain and a secondary hood. The resultant costs, \$197,100 for an air curtain and \$125,100 for a secondary hood, were used to estimate air curtain secondary hood costs for the low arsenic throughput smelters based on the number of converters listed in Table 6-6 for each smelter. Electrical system costs were estimated for each capture system based on data from the ASARCO report.⁸ Ductwork costs were

Table 6-7. ESTIMATED CAPITAL COSTS OF AIR CURTAIN SECONDARY HOOD CAPTURE SYSTEMS FOR PRIMARY COPPER SMELTERS
(December 1982 dollars)

Smelter	Capital cost, \$			
	Air curtain secondary hood	Ductwork	Electrical	Total
1. ASARCO - El Paso	966,600	350,000	58,600	1,375,200
2. ASARCO - Hayden	1,611,000	0	90,700	1,701,700
3. Tennessee Chemical Co. - Copperhill	644,400	1,631,200	42,600	2,318,200
4. Inspiration - Miami	1,611,000	3,981,900	90,700	5,683,600
5. Kennecott - Garfield	1,288,800	0	74,600	1,363,400
6. Kennecott - Hayden	966,600	2,444,000	58,600	3,469,200
7. Kennecott - Hurley	1,288,800	3,255,000	74,600	4,618,400
8. Kennecott - McGill	1,288,800	3,255,000	74,600	4,618,400
9. Magma - San Manuel	1,933,100	5,171,000	106,700	7,210,800
10. Phelps Dodge - Ajo	966,600	2,444,000	58,600	3,469,200
11. Phelps Dodge - Douglas	1,611,000	3,981,900	90,700	5,683,600
12. Phelps Dodge - Hidalgo	966,600	2,444,000	58,600	3,469,200
13. Phelps Dodge - Morenci	2,899,800	0	154,600	3,054,400
14. Copper Range - White Pine	644,400	1,631,200	42,600	2,318,200

estimated based on the duct requirements listed in Table 6-6 and an assumption that an additional 40 percent of duct material is required for use as support structures.

Capital costs for fabric filters - Table 6-8 presents estimated capital costs for fabric filters required for the collection of captured fugitive emissions. The table also summarizes the capital costs for air curtain secondary hoods from Table 6-7 and presents the capital costs for the total system consisting of air curtain secondary hoods and a fabric filter for each smelter. These cost estimates were obtained by calculating costs for a fabric filter, 43 m (140 ft) of ductwork, and a 61 m (200 ft) stack for each smelter. The exhaust fan capacities listed in Table 6-6 were used to size equipment. The fabric filter costs were based on cost estimates contained in the IGCI report.⁹ The IGCI report presents cost estimates in fourth quarter 1977 dollars for fabric filters treating offgases from reverberatory furnaces at two smelters and was prepared by several fabric filter manufacturers. The costs were developed for a 2-to-1 filter cloth-to-air ratio. Both reverse air and shaker type mechanisms were suggested for bag cleaning.

Ductwork costs were estimated based on a total of 43 m (140 ft) of ductwork assumed to be needed for venting offgases from the fabric filter to the stack, and a unit cost of \$11,355/Mg (\$10,300/ton) of ductwork weight. The unit cost includes 40 percent additional material to be used for support structures.

The capital cost for the stack was based on data contained in a report prepared for EPA.¹⁰ The report presented capital cost estimates in December 1977 dollars for different sized stacks.

The reported costs for fabric filters and stacks were escalated to December 1982 dollars using the Chemical Engineering Plant Cost Index (December 1982 = 314.3). Total capital cost for the fabric filter collection equipment was obtained by adding the costs for the fabric filter, ductwork, and stack, plus a 25 percent retrofit factor. A mathematical expression is developed to relate the total capital costs of fabric filter collection equipment to gas flow rate. The resultant expression is:

Table 6-8. ESTIMATED CAPITAL COSTS OF AIR CURTAIN SECONDARY
HOODS AND FABRIC FILTERS FOR PRIMARY COPPER SMELTERS
(December 1982 dollars)

Smelter	Capital cost, \$		
	Air curtain secondary hoods	Fabric filter	Total
1. ASARCO - El Paso ^a	1,375,200	0	1,375,200
2. ASARCO - Hayden ^b	1,701,700	0	1,701,700
3. Tennessee Chemical Co. - Copperhill	2,318,200	2,115,700	4,433,900
4. Inspiration - Miami	5,683,600	4,141,300	9,824,900
5. Kennecott - Garfield	1,363,400	3,833,800	5,197,200
6. Kennecott - Hayden	3,469,200	3,262,000	6,731,200
7. Kennecott - Hurley	4,618,400	4,141,300	8,759,700
8. Kennecott - McGill	4,618,400	4,141,300	8,759,700
9. Magma - San Manuel	7,210,800	5,838,800	13,049,600
10. Phelps Dodge - Ajo	3,469,200	3,262,000	6,731,200
11. Phelps Dodge - Douglas	5,683,600	4,141,300	9,824,900
12. Phelps Dodge - Hidalgo	3,469,200	3,262,000	6,731,200
13. Phelps Dodge - Morenci	3,054,400	5,471,300	8,525,700
14. Copper Range - White Pine	2,318,200	2,115,700	4,433,900

^aThe captured gases will be treated in an existing fabric filter collection system.

^bThe cost of collection system for the captured fugitive emissions was included in the baseline.

C = Total capital cost of fabric filter collection equipment,
December 1982 dollars

$$= (\text{Retrofit factor}) [\text{Capital cost of fabric filter } (C_1) \\ + \text{Capital cost of ductwork } (C_2) + \text{Capital cost of} \\ \text{stack } (C_3)]$$

$$= (125\%) [24,430 (Q_4)^{0.96} + 19,428 (Q_4)^{0.5} + 22,300 (Q_4)^{0.49}]$$

where Q_4 = Actual flow rate at the inlet of fabric
filter (i.e., fan exhaust flow listed in Table 6-6), m^3/s

$$= 24,285 [1.26 (Q_4)^{0.96} + (Q_4)^{0.5} + 1.15 (Q_4)^{0.49}]$$

Annualized costs for air curtain secondary hood capture and fabric filter collection system - Table 6-9 presents the annualized costs for air curtain secondary hood capture and fabric filter collection systems. The costs were estimated using the cost bases discussed earlier and the following labor and utility requirements:

- 2 manhours/shift for operating and maintenance labor for capture equipment and 2 manhours/shift operating and maintenance labor for a $66 \text{ m}^3/\text{s}$ (140,000 acfm) fabric filter.
- 2 manhours/shift operating and maintenance labor for capture equipment and 2.5 manhours/shift operating and maintenance labor for a $109 \text{ m}^3/\text{s}$ (230,000 acfm) fabric filter.
- 4 manhours/shift operating and maintenance labor for capture equipment and 4 manhours/shift operating and maintenance labor for a $142 \text{ m}^3/\text{s}$ (300,000 acfm) and a $208 \text{ m}^3/\text{s}$ (440,000 acfm) fabric filter.
- Electricity requirements at 7.5 kPa (30 in. H_2O) for air curtains, 5.5 kPa (22 in. H_2O) for secondary hoods, and 1.5 kPa (6 in. H_2O) for fabric filters.

6.3.2 Matte and Slag Tapping Controls

Fugitive emission control equipment for matte tapping and slag tapping operations includes a local ventilation capture and a fabric filter collection system. All of the smelters currently capture fugitive emissions from the matte tapping operations. One smelter,

Table 6-9. ESTIMATED ANNUALIZED COSTS OF AIR CURTAIN
SECONDARY HOODS AND FABRIC FILTERS FOR PRIMARY
COPPER SMELTERS^a

Smelter	Annual operating cost, \$				
	Utilities	Labor	Maintenance material	Indirect Costs	Total
1. ASARCO - El Paso	117,600	0	0	189,100	306,700
2. ASARCO - Hayden	174,400	0	0	233,980	408,400
3. Tennessee Chemical Co. - Copperhill	455,200	87,200	29,900	705,300	1,277,600
4. Inspiration - Miami	1,123,900	145,700	59,800	1,513,400	2,842,800
5. Kennecott - Garfield	372,400	87,300	29,900	810,300	1,300,000
6. Kennecott - Hayden	819,000	94,600	37,400	1,030,600	1,981,600
7. Kennecott - Hurley	1,123,900	145,700	59,800	1,367,000	2,696,400
8. Kennecott - McGill	1,123,900	145,700	59,800	1,367,000	2,696,400
9. Magma - San Manuel	1,816,500	145,700	59,800	1,956,800	3,978,800
10. Phelps Dodge - Ajo	636,000	0	0	925,000	1,561,500
11. Phelps Dodge - Douglas	1,123,900	145,700	59,800	1,513,400	2,842,800
12. Phelps Dodge - Hidalgo	819,000	0	0	925,500	1,744,500
13. Phelps Dodge - Morenci	522,700	87,300	29,900	1,268,000	1,908,000
14. Copper Range - White Pine	455,200	87,200	29,900	705,300	1,277,600

ASARCO-El Paso, collects the captured emissions from the matte tapping operation. The existing capture equipment was assumed to be adequate and thus was not included in the control cost estimate. For ASARCO-Hayden, the matte and slag tapping capture and control costs were included in the baseline, and therefore, were not estimated in this analysis.

A majority of smelters capture fugitive emissions from the slag tapping operations. For those smelters that do not have slag tapping capture systems presently, slag tapping capture system costs were estimated based on a typical exhaust volume flow rate of $14.2 \text{ m}^3/\text{s}$ (30,000 acfm). This flow rate was based on exhaust flow rates from the slag tapping operations at a number of smelters. The capture system for slag tapping operations includes tap port hoods, slag launder hoods, sufficient length of duct to move the captured emissions from the launder hoods to the fan and then to the main duct, and hoods over slag ladles. The total cost, including slag launder hoods, ducting, plenum chamber, support steel, and foundation would be \$46,000 for a slag tapping capture system. Fan costs were not included in the capture system but were included in the collection system. The annualized operating costs were based on 2 manhours of maintenance labor per week, electricity requirements for an 80 hp fan, capital recovery at 15 years of equipment life, and administrative overhead, taxes, and insurance at 4 percent of capital costs.

The capital costs developed for fabric filter collection systems for captured gases were based on data from the IGCI report prepared for EPA. The reported costs for the fourth quarter of 1977 were escalated to December 1982 dollars using the Chemical Engineering Plant Cost Index (December 1982 = 314.3). The costs were estimated for a $35.4 \text{ m}^3/\text{s}$ (75,000 acfm) capacity fabric filter system based on typical ventilation rates of $18.9 \text{ m}^3/\text{s}$ (40,000 acfm) from matte tapping operations and $16.5 \text{ m}^3/\text{s}$ (35,000 acfm) from slag tapping operations. Sixty-one meter (200 ft) long ductwork was included in the cost estimate. Annualized operating costs were estimated using the cost bases discussed earlier, the labor requirements of 2 manhours/shift operating labor and 1 manhour/shift maintenance labor³, and fan power requirements at 1.5 kPa (6 in. water). Tables 6-10 and 6-11 present the capital and annualized costs

Table 6-10. ESTIMATED CAPITAL COSTS OF ADD-ON FUGITIVE EMISSION
CAPTURE AND COLLECTION SYSTEMS FOR MATTE
AND SLAG TAPPING OPERATIONS
(December 1982 dollars)

Smelter	No. of smelting furnaces	Cost, \$1,000		
		Local venti- lation capture system ^a	Fabric filter collection system ^b	Total
1. ASARCO - El Paso	1	0	370 ^c	370
2. ASARCO - Hayden	2	0	0	0
3. Tennessee Chemical Co. - Copperhill	1	0	894	894
4. Inspiration-Miami	1	29	894	923
5. Kennecott - Garfield	3	0	1,786	1,786
6. Kennecott - Hayden	1	0	894	894
7. Kennecott - Hurley	2	58	894	952
8. Kennecott - McGill	2	0	894	894
9. Magma - San Manuel	3	0	1,786	1,786
10. Phelps Dodge - Ajo	1	0	894	894
11. Phelps Dodge - Douglas	3	0	1,786	1,786
12. Phelps Dodge - Hidalgo	1	0	894	894
13. Phelps Dodge - Morenci	5	0	1,786	1,786
14. Copper Range - White Pine	2	0	894	894

^a Local ventilation system costs were based on \$29,000 dollars per smelting furnace.

^b Collection system costs were based on one fabric filter unit for smelters with one or two smelting furnaces and two fabric filter units for smelters with three or more smelting furnaces.

^c For system collecting the captured emissions from the slag tapping operation only (captured emissions from matte tapping operations are currently collected in an existing ESP system.)

Table 6-11. ESTIMATED ANNUALIZED COSTS OF ADD-ON FUGITIVE EMISSION
CAPTURE AND COLLECTION SYSTEMS FOR MATTE
AND SLAG TAPPING OPERATIONS
(December 1982 dollars)

Smelter	No. of operating smelting furnaces ^a	Costs, \$1,000		
		Local venti- lation capture system ^a	Fabric filter collection system	Total
1. ASARCO - El Paso	1	0	153 ^b	153
2. ASARCO - Hayden	1	0	0	0
3. Tennessee Chemical Co. - Copperhill	1	0	257	257
4. Inspiration - Miami	1	4	257	261
5. Kennecott - Garfield	2	0	514	514
6. Kennecott - Hayden	1	0	257	257
7. Kennecott - Hurley	1	8	257	265
8. Kennecott - McGill	1	0	257	257
9. Magma - San Manuel	2	0	514	514
10. Phelps Dodge - Ajo	1	0	257	257
11. Phelps Dodge - Douglas	2	0	514	514
12. Phelps Dodge - Hidalgo	1	0	257	257
13. Phelps Dodge - Morenci	2	0	514	514
14. Copper Range - White Pine	1	0	257	257

^aFor the purpose of this table, the number of operating smelting furnaces is defined as the total number of smelters that may be tapped at a time.

^bFor system collecting the captured emissions from the slag tapping operation only. (The captured emissions from the matte tapping operation are currently collected in an existing ESP.)

for the smelter matte and slag tapping fugitive emission capture and collection systems.

6.4 COSTS OF REGULATORY ALTERNATIVES

This section presents the costs associated with the implementation of the regulatory alternatives defined in Section 4.0 and listed in Table 6-1. A compilation of the capital and annualized costs for each of the regulatory alternatives for the smelters processing low arsenic feed is presented in Table 6-12.

6.5 COST EFFECTIVENESS

The purpose of deriving cost effectiveness is to illustrate the differences in cost relative to the arsenic emission reduction achievable for each regulatory alternative analyzed. Cost effectiveness is defined as incremental annualized costs in dollars per unit of pollutant removed over the baseline.

Table 6-13 summarizes incremental annualized costs and cost effectiveness for the regulatory alternatives for low arsenic feed smelters individually. The table also presents annual emissions and emission reductions projected over the baseline.

Table 6-12. SUMMARY OF INCREMENTAL COSTS OF REGULATORY ALTERNATIVES OVER BASELINE
FOR CONTROL OF ARSENIC EMISSIONS FOR LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS
(Costs in \$1,000's December 1982 dollars)

Smelter	Baseline (Existing process and fugitive controls) ^a		Effective process controls		Effective process controls, and effective fugitive controls for converters only		Effective process controls, and effective fugitive controls for smelter matte and slag tapping and converter operations ^d	
	Capital cost	Annualized cost	Capital cost	Annualized cost	Capital cost	Annualized cost	Capital cost	Annualized cost
1. ASARCO - El Paso	46 ^e	40 ^e	0	0	1,375	307	370	153
2. ASARCO - Hayden	75,606 ^f	24,698 ^f	0	0	1,702	408	0 ^g	0 ^g
3. Tennessee Chemical Co. - Copperhill	0	0	0	0	4,434	1,278	894	257
4. Inspiration - Miami	0	0	0	0	9,825	2,843	923	261
5. Kennecott - Garfield	0	0	0	0	5,197	1,300	1,786	514
6. Kennecott - Hayden	0	0	0	0	6,731	1,982	894	257
7. Kennecott - Hurley	54,044 ^h	17,111 ^h	0	0	8,760	2,696	952	265
8. Kennecott - McGill	0	0	10,018 ⁱ	4,127 ⁱ	8,760	2,696	894	257
9. Hagma - San Manuel	0	0	0	0	13,050	3,980	1,786	514
10. Phelps Dodge - Ajo	51,067 ^j	16,356 ^j	0	0	6,731	1,562	894	257
11. Phelps Dodge - Douglas	0	0	0	0	9,825	2,843	1,786	514
12. Phelps Dodge - Hidalgo	0	0	0	0	6,731	1,745	894	257
13. Phelps Dodge - Morenci	95,294 ^j	30,815 ^j	0	0	8,526	1,908	1,786	514
14. Copper Range - White Pine	0	0	0	0	4,434	1,278	894	257
Total	276,057	89,020	10,018	4,127	96,081	26,826	14,753	4,277

Footnotes are given on next page.

Table 6-12. SUMMARY OF INCREMENTAL COSTS OF REGULATORY ALTERNATIVES OVER
 BASELINE FOR CONTROL OF ARSENIC EMISSIONS FOR LOW ARSENIC THROUGHPUT
 PRIMARY COPPER SMELTERS
 (concluded)

- ^aExisting fugitive controls include effective capture and collection of roaster fugitive emissions at calcine feed smelters, effective capture of smelter matte tapping fugitive emissions at all smelters with the collection of captured emissions only at the ASARCO-El Paso smelter; effective capture of slag tapping fugitive emissions at some smelters; and an effective fabric filter collection system to be used for converter fugitive emissions at ASARCO-El Paso.
- ^bEffective process controls include spray chamber cooling and ESP collection systems for process particulate matter emissions from roasters, smelters, and converters.
- ^cEffective fugitive controls for converters include air curtain secondary hood capture followed by fabric filter collection systems.
- ^dEffective fugitive controls for smelter matte and slag tapping operations include local ventilation hood capture followed by a fabric filter collection system.
- ^eRepresents the cost of installation of a fugitive emission capture system for the smelter slag tapping operation. ASARCO is required to install a fugitive emission capture system for the smelter slag tapping operation by July 1, 1987, under the agreement reached with OSHA.
- ^fRepresents the cost of process modification to the smelter. The existing smelting process is being modified or will be modified to convert to the INCO smelting process in order to satisfy the accord reached between ASARCO Smelting Co. and EPA.
- ^gThe furnace matte and slag tapping emission capture and collection costs are included in the cost of process modification to the smelter shown under the baseline.
- ^hRepresents the cost of process modification to the smelter. Kennecott Copper Company has announced that it plans to convert the existing smelting process at the Hurley smelter to the INCO process.
- ⁱRepresents the cost of new evaporative cooling and ESP control systems for the smelter furnace and converter process emissions.
- ^jRepresents the cost of process modification to the smelter. The existing smelting process is being modified or will be modified to convert to oxygen sprinkling/oxygen fuel smelting process in order to satisfy the accord reached between Phelps Dodge Copper Co. and EPA.

Table 6-13. EMISSION REDUCTION AND COST EFFECTIVENESS IMPACTS FOR
LOW-ARSENIC THROUGHPUT PRIMARY COPPER SMELTERS

Smelter	Baseline			Alternative II			Alternative III			Alternative IV		
	Arsenic feed rate, kg/hr	Arsenic emissions, kg/yr	Reduction from baseline, kg/yr	Annualized cost, 10 ³ \$/yr	Cost effectiveness \$/kg	Arsenic emissions, kg/yr	Reduction from baseline, kg/yr	Annualized cost, 10 ³ \$/yr	Cost effectiveness \$/kg	Arsenic emissions, kg/yr	Reduction from baseline, kg/yr	Annualized cost, 10 ³ \$/yr
1. ASARCO - El Paso	142	47.3	0	0	--	28.4	18.9	307	16,700	47.3	0	0
2. ASARCO - Hayden	170	54.2	0	0	--	29.2	25.0	408	16,300	54.2	0	0
3. Tennessee Chemical Co. - Copperhill	1.3	0.8	0	0	--	0.2	0.6	1,276	2,130,000	0.7	0.1	257
4. Inspiration - Hualar	10	3.4	0	0	--	1.7	1.7	2,843	1,672,000	2.6	0.8	261
5. Kennecott - Garfield	118	39.6	0	0	--	32.7	6.9	1,300	186,400	37.8	1.8	514
6. Kennecott - Hayden	0.0	35.3	0	413	--	29.2	6.1	1,902	324,900	34.4	0.9	257
7. Kennecott - Marley	1.0	0.8	0	0	--	0.3	0.5	2,696	5,392,000	0.7	0.1	265
8. Kennecott - McGill	81	448.1	161.7	4,127	25,500	406	41.1	2,696	64,000	443.8	4.3	257
9. Hays - San Manuel	2.0	12.0	0	0	--	11.2	0.8	3,980	4,975,000	12.0	0	514
10. Phelps Dodge - Rjo	47	36.1	0	0	--	33.5	2.6	1,562	608,800	35.3	0.8	257
11. Phelps Dodge - Douglas	11	43.0	0	0	--	38.7	4.3	2,843	55,800	42.1	0.9	514
12. Phelps Dodge - Kidojo	14	4.3	0	0	--	2.6	1.7	1,745	1,026,500	3.4	0.9	257
13. Phelps Dodge - Norwest	4.5	9.5	0	0	--	3.4	6.1	1,908	312,900	8.6	0.9	514
14. Copper Range - White Pine	0.7	2.6	0	0	--	1.7	0.9	26,826	1,470,000	2.6	0	257
TOTALS		737	161.7	4,127	25,500	618.8	118.2	26,826	277,000	725.5	11.5	4,277
												371,900

6.6 REFERENCES

1. Survey of Current Business. November 1982. Primary Metal Industry Labor Costs. December 1982.
2. Monthly Energy Review. October 1982. Electricity Costs. DOE/EIA-003583/01. January 1983.
3. GARD Inc. Capital and Operating Costs of Selected Air Pollution Control Systems. U.S. Environmental Protection Agency. EPA Report No. EPA 450/5-80-002. December 1978.
4. PEDCo Environmental, Inc. Cost Estimate and Comparisons for Converting from Reverberatory Furnace Smelting to Oxygen Flash/Sprinkling Smelting. (Draft) U.S. Environmental Protection Agency. EPA Contract No. 68-03-2024. November 1982.
5. Industrial Gas Cleaning Institute. Cost Estimates of Upgrading Particulate Matter Controls in Copper Smelter Reverberatory Furnaces. U.S. Environmental Protection Agency. EPA Contract No. 68-02-2532. Task No. 2, March 1977.
6. U.S. Environmental Protection Agency. Draft Standards Support and Environmental Impact Statement. Volume 1: Proposed National Emission Standards for Arsenic Emissions from Primary Copper Smelters. Research Triangle Park, NC. June 1978.
7. The Metallurgical Society of AIME. Copper and Nickel Converters. Proceedings of a Symposium on Converter Operating Practices sponsored by the TMS-AIME Pyrometallurgy
8. ASARCO Incorporated Converter Secondary Hooding, Tacoma Plant. Salt Lake City. Utah. January 22, 1981.
9. Reference 5.
10. Reference 3.

7.0 ECONOMIC IMPACT

This section first presents an economic profile of the primary copper industry in general, and primary copper smelters in particular (Section 7.1). The data presented in the economic profile is then used in an economic analysis of the industry (Sections 7.2 and 7.3). The economic profile focuses on several primary copper smelter industry characteristics, such as: number and location of smelters, copper supplies, copper demand, competition, substitutes, and prices.

7.1 INDUSTRY ECONOMIC PROFILE

7.1.1 Introduction

Copper's utility stems from its qualities of electrical and thermal conductivity, durability, corrosion resistance, low melting point, strength, malleability, and ductility. Principal uses are in transportation, machinery, electronics, and construction.

The Standard Industrial Classification Code (SIC) definition of the primary copper industry is the processes of mining, milling, smelting, and refining copper. The primary copper smelters are included in SIC 3331 (Primary Smelting and Refining of Copper). Copper-bearing ore deposits and substantial amounts of copper scrap provide the raw materials for these processes.

In addition to producing copper, the industry markets by-product minerals and metals that are extracted from the ore deposits, such as silver, gold, zinc, lead, molybdenum, selenium, arsenic, cadmium, titanium, and tellurium. Many of the companies that own primary copper facilities also fabricate copper. Many of these same companies are also highly diversified and produce other metals, minerals, and fuels.

The standard under consideration directly affects only one of the four primary copper processes, namely smelting. However, the other three related processes are an integral part of the ownership and economic structures of copper smelters and therefore must be considered in determining industry

impact. Mining and milling processes supplying a smelter will be secondarily affected by a smelter impact because transportation costs to an alternate smelter will add a sizeable business cost. Transportation costs for concentrate are significant because only 25 to 35 percent of the concentrate is copper and the remaining 75 to 65 percent that is also being transported is waste material. The same interdependence between smelter and refinery is not as critical because the copper content after leaving the smelter is typically 98 percent.

Even if there were no business dependencies among the processes, the available financial data for smelters are aggregated in consolidated financial statements which makes smelter data difficult to isolate. Thus, an economic analysis of copper smelters must be cognizant of the economic connection backward to the mines and forward through the refining stage.

7.1.2 Market Concentration

Fifteen pyrometallurgical copper smelters exist in the United States. Copper is also produced in limited amounts by various hydrometallurgical methods which by-pass the smelting stage. These hydrometallurgical facilities are not being considered in the standard setting process. The 15 copper smelters have a capacity* of 1,722,600 megagrams** of copper. The hydrometallurgical processes have a capacity of roughly 10 percent of the copper smelters' capacity.

Table 7-1 shows that the vast majority (approximately 89 percent) of smelting capacity is located in the southwestern States of Utah, Nevada, New Mexico, Arizona, and Texas, close to copper mines. The location is largely dictated by the need to minimize shipping distances of concentrates, which are normally 25 percent to 35 percent copper.

The 15 U.S. copper smelters are owned by 7 large companies. All 7 companies are integrated in that, to various degrees, they own some mining and milling facilities which produce copper concentrates for the smelters. Several smelters, apart from the concentrates from their own mines, buy additional concentrates from other mining and milling producers,

*Capacity is not a static measure of a smelter since capacity can vary, for example, according to the grade of copper concentrates processed.

**1 megagram = 1.1 short tons.

Table 7-1. SMELTER OWNERSHIP, PRODUCTION AND SOURCE MATERIAL ARRANGEMENTS^a

Smelter Name and Location	Ownership	1980 Rated ^d		1979		1980		Material Arrangements	
		Capacity (Mg)	Production (Mg)	Capacity (Mg)	Production (Mg)	1979	1980	1979	1980
Tacoma, WA	ASARCO, Inc.	91,000	61,000 ²	91,000	42,700 ²	Integrated	-	31%	20%
Hayden, AZ		182,000	96,000	182,000	59,000	Custom	-	25%	44%
El Paso, TX		91,000	85,000	91,000	47,300	Toll	-	44%	36%
Copperhill, TN	Cities Service Co.	13,600	12,900 ³	13,600	10,000 ³	Integrated ^b	-	100%	100%
White Pine, MI	Copper Range Co.	52,000	39,770 ⁴	52,000	32,500 ⁴	Integrated	-	100%	100%
	Subsidiary of The Louisiana Land Exploration Co.								
Miami, AZ	Inspiration Consolidated Copper Company	136,000	124,070 ⁵	136,000	107,400 ⁵	Integrated	-	35%	58%
						Toll	-	65%	42%
McGill, NV	Kennecott Corp.	45,000		45,000		Integrated	-	100%	97%
Garfield, UT		254,000	296,000 ⁶	254,000	259,300 ⁶				
Hayden, AZ		71,000		71,000					
Hurley, NM		73,000 ^c	56,360	73,000 ^c	46,100	Toll	-		10%
Magma (San Manuel, AZ)	Newmont Mining	181,000	145,900 ⁷	181,000	98,000 ⁷	Integrated	-	100%	100%
						Toll	-		
Douglas, AZ	Phelps Dodge Corp.	115,000		115,000		Integrated	-	-	75%
Ajo, AZ		64,000	283,000 ⁸	64,000	324,100 ⁸	Custom	-	-	-
Morenci, AZ		191,000		191,000		Toll	-	-	25%
Hidalgo, NM		163,000	91,000	163,000					
Total Production		1,722,600 ^d	1,291,000 (74.9%)	1,722,600 ^d	1,026,420 (59.6%)	Integrated	-	73%	6%
Operating Rate						Custom	-	6%	21%
						Toll	-		

^aInformation primarily from corporate 10-K reports to the Securities and Exchange Commission.

^bEstimate based on total copper sales for Cities Service minus the sales of its Arizona mines.

^cEstimated to expand to 110,000 tons.

^dRated capacity excluding Anaconda smelter which was closed in 1980 (rated at 180,000 Mg).

smelt and refine the copper, and then sell it. This practice is referred to as custom smelting. Other smelters process (smelt and refine) the concentrates, and return the blister copper to mine owners for them to sell, a practice referred to as tolling. Some smelters perform both toll and custom smelting.

It is general industry practice for companies to operate their smelters as service centers at low profit margins to the owned mines. This acts to shift profits of an integrated operator to the mines, where depletion allowances exist. This maximizes profit to the overall operation. An implication of this policy is that the impact on profits from swings in copper prices is frequently manifest at the mines more than the smelters.

Table 7-1 lists the smelters, their corporate owners, capacities, 1979 and 1980 production amounts, and the distribution of integrated, custom, and toll smelting. Total production figures and the corresponding operating rates shown in Table 7-1 are compiled from corporate reports. Figures in Table 7-1 are adjusted to exclude capacity and production for the Anaconda smelter, which was closed in 1980. For 1979, the table shows a 74.9 percent operating rate. For 1980, the table shows that the industry operated at 59.6 percent of capacity. Production was down for 1980 due to an industry strike. Following the strike in 1980, production improved in 1981 to 1,380 gigagrams, for a capacity utilization rate of 80 percent.⁹ Preliminary figures for 1982 from the Bureau of Mines show a decline in primary copper smelter production to 1,020 gigagrams, for a capacity utilization rate of about 59 percent.¹⁰

The 3 largest companies account for 78 percent of the entire smelting capacity. Phelps Dodge Corporation has the largest smelting capacity, followed by Kennecott Corporation and then ASARCO. The remaining 4 companies each have 1 smelter and in order of size are Magma (Newmont), Inspiration, Copper Range, and Copperhill (Cities Service).

The table also shows that 73 percent of total 1980 smelter production was from concentrate from integrated arrangements. Of the remaining concentrate, 21 percent was smelted on a toll basis and 6 percent smelted on a custom basis. Three of the 8 companies process only their own copper concentrates.

7.1.3 Total Supply

Copper resources are defined as deposits which can be profitably extracted at a given price. Various estimates of U.S. copper resources show amounts ranging from 61.8 teragrams to 99.1 teragrams.* The capability of copper resources to meet future demand is dependent upon several factors; a principal one being the rate of growth in demand. The U.S. Bureau of Mines estimates that copper demand will grow at an annual growth rate of 3.0 percent to the year 2000 and that 30 percent of the demand will be supplied by scrap. Therefore, the likely primary copper demand over this period would be 55 teragrams compared with 92 teragrams of resources.¹¹ Consequently, U.S. supply appears adequate to the year 2000. Beyond the year 2000, demand is expected to strain supply sources. However, increased uses of old scrap and possible exploitation of sea nodules can supplement on-shore mining. In addition, microminiaturization, copper cladding, and other conservation methods will be more widely used to extend the supply of copper.

7.1.3.1 Domestic Supply. Primary refined copper output alone does not depict the entire supply of copper that is available for consumption in the United States. A large portion of copper scrap does not need to be resmelted or re-refined and is readily available for consumption. Copper is a durable material and, if it is unalloyed or unpainted, etc., it can be reused readily. Otherwise, it is resmelted or re-refined as described earlier. The ready availability of copper scrap as a secondary source of supply tends to be a stabilizing influence on producers' copper prices.

The total supply of copper available for consumption in any one year is therefore comprised of refined U.S. production, scrap not re-refined, net imports, and any changes in inventory of primary refined production from one year to the next.

The refined copper production in 1981 comprised 70.4 percent of total copper consumed in the United States; scrap not re-refined accounted for 32.0 percent and net refined imports 10.6 percent (total exceeds 100 percent due to stock changes).¹² Between 1970 and 1981, 67 percent of U.S. copper demand, excluding stock changes, was met from domestic mine production; 21

*Teragram is 1.1 million short tons.

percent was from old scrap, and 12 percent from net imports. During these years, total U.S. demand for copper averaged 2,012,000 megagrams per year. Of this amount, 1,337,000 megagrams was from domestic production, 427,000 megagrams from scrap, and 248,000 megagrams from net imports.

Another statistic for describing the importance of scrap is to total the three stages (smelting, refining from scrap, and reuse of scrap) at which scrap can enter the production process, and compare the figures to total copper consumption. In 1981 the percentage of total consumed copper from scrap was 47.7, roughly the same as in recent years.

The 1981 refined copper production level was 1,956,400 megagrams. Although the average for the past several years has shown some improvement, total refined copper production has not returned to the 1973 peak level.

7.1.3.2 World Copper. According to the Bureau of Mines, the world reserve of copper in ore is estimated at 494,000 gigagrams of copper. In addition, an estimated 1,333,000 gigagrams of copper are contained in other land-based resources, and another 689,000 gigagrams in seabed nodules. The United States accounts for 19 percent of known copper reserves and 26 percent of other land-based copper resources.¹³

The United States is the leading copper producing and consuming country. Other major copper mining countries include: Chile, the U.S.S.R., Canada, Zambia, Zaire, Peru, and Poland. Although its copper mining activity is quite small, Japan is among the three largest countries in terms of copper smelting and refining. In 1981 the U.S. produced 18.8 percent of the world's mine production of copper, 16.5 percent of the smelter production, and 22.2 percent of the refinery production. The consumption of the world's refined copper by the U.S. amounted to about 21 percent. Table 7-2 shows U.S. production, world production, and the U.S. percent of world production for the years 1963 through 1981. Although the U.S. is essentially maintaining its consumption and production levels, world consumption and production is increasing. As a result, the U.S. share of world consumption and production shows a relative decrease.

In 1981 world consumption of refined copper rose 9 percent to 9,440 gigagrams.¹⁴ Stocks of refined copper in the market economy countries increased 5 percent to 1,100 gigagrams.¹⁵

Table 7-2. UNITED STATES AND WORLD COMPARATIVE TRENDS IN COPPER PRODUCTION: 1963-1981 16,17
(Gigagrams)

Years	Mine Production of Copper (Copper Content)			Smelter Production of Copper			Production of Refined Copper		
	U.S.	World	U.S. as Percent of World	U.S.	World	U.S. as Percent of World	U.S.	World	U.S. as Percent of World
1963	1100.6	4624.3	23.8	1176.3	4634.8	25.4	1709.5	5399.7	31.7
1964	1131.1	4798.6	23.6	1214.2	4851.4	25.0	1805.7	5739.0	31.5
1965	1226.3	4962.7	24.7	1300.9	5024.4	25.9	1942.1	6058.5	32.1
1966	1296.5	5215.9	24.9	1330.3	5167.0	25.7	1980.7	6322.2	31.3
1967	865.5	5057.6	17.1	782.3	4891.0	16.0	1384.9	6000.5	23.1
1968	1092.8	5456.5	20.0	1148.9	5507.8	20.9	1668.3	6658.6	25.1
1969	1401.2	5951.2	23.5	1438.3	5972.9	24.1	2009.3	7199.8	27.9
1970	1560.0	6387.3	24.4	1489.0	6309.5	23.6	2034.5	7577.8	26.8
1971	1380.9	6473.9	21.3	1360.8	6380.0	21.3	1780.3	7377.8	24.1
1972	1510.3	7071.5	21.4	1533.5	7003.2	21.9	2048.9	8068.0	25.4
1973	1558.5	7591.4	20.5	1582.1	7445.5	21.2	2098.0	8497.3	24.7
1974	1445.7	7885.6	18.3	1424.2	7933.6	18.4	1938.3	8851.5	21.9
1975	1282.2	6968.2	18.4	1357.5	7535.4	18.0	1610.7	8402.0	19.2
1976	1456.6	7525.3	19.4	1438.5	7839.6	18.3	1736.7	8322.3	20.9
1977	1364.4	7755.8	17.6	1346.8	8136.9	16.6	1706.9	8649.8	19.7
1978	1357.6	7618.3	17.8	1343.0	8017.5	16.8	1869.2	8791.9	21.3
1979	1443.6	7674.4	18.8	1396.0	8045.6	17.4	2013.8	8903.1	22.6
1980	1181.1	7656.3	15.4	1053.3	7938.9	13.3	1726.0	8971.0	19.2
1981	1538.2	8171.1	18.8	1377.7	8324.7	16.5	2037.6	9184.4	22.2
Average Annual Compound Growth Rate (Percent)									
1963-1973	3.54	5.08	-	3.01	4.85	-	2.07	4.64	-
1964-1974	2.48	5.09	-	1.61	4.77	-	0.71	4.43	-
1971-1981	1.09	2.36	-	0.12	1.03	-	1.36	2.21	-

Note: One gigagram = 1,000 megagrams. One megagram (1,000 kilograms) equals 1.102311 short tons (907.185 kilograms = 2000 pounds avoirdupois, where one pound avoirdupois equals 0.453592 kilogram or 453.5924 grams).

7.1.4 U.S. Total Consumption Of Copper

Total copper consumed in the United States over the last 12 years has fluctuated considerably but shows an overall upward trend. However, copper consumption has not returned to its 1973 peak. This conclusion is derived from data on copper consumption from refineries and copper consumption from refineries plus scrap.

Table 7-3 shows each set of data for the years 1970 through 1981. The 5-year averages in gigagrams for copper consumption from refineries has increased by 6.9 percent (1972 through 1976 is 1,891.9 and 1977 through 1981 is 2,021.5.). Five-year scrap consumption has shown an increase of 5.1 percent, from 848.6 gigagrams for the 1972 to 1976 period, to 892.3 gigagrams for the 1977 to 1981 period. There are signs that the consumption of scrap has begun to increase over the last few years.

The Bureau of Mines forecasts a long-range overall consumption growth rate to the year 2000 of 3.0 percent per year. The combined 3.0 percent growth rate is composed of a 2.4 percent growth rate for primary copper, and a 4.8 percent growth rate for secondary copper.¹⁹

7.1.4.1 Demand By End-Use. Refined copper and copper scrap are further processed in a number of intermediate operations before the copper is consumed in a final product. Refined copper usually consists of one of the following shapes: cathodes, wire bars, ingots, ingot bars, cakes, slabs, and billets. These shapes plus the copper scrap then go to brass mills, wire mills, foundries, or powder plants for subsequent processing. The copper is frequently alloyed and transformed into other shapes such as sheet, tube, pipe, wire, powder, and cast shapes. Ultimately, the copper is consumed in such shapes in five market or end-use categories. The Copper Development Association, Inc. uses the following categories: building construction, transportation, consumer and general products, industrial machinery and equipment, and electrical and electronic products.

Table 7-4 shows the demand for copper in each of these five markets over the 12-year period 1970 through 1981. The total figures for these five markets will not equal the total consumption figures of Table 7-3

Table 7-4. U.S. COPPER DEMAND BY MARKET END USES²⁰(Gigagrams)^a

Market	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981 ^b
Building Constr.	748	830	923	998	795	634	780	888	956	951	774	816
Transportation	267	307	345	402	332	265	372	412	422	388	270	310
Consumer and General Products	369	358	417	413	402	316	328	340	388	420	342	376
Industrial Machinery and Equipment	560	540	601	640	563	404	483	518	551	565	501	537
Electrical and Electronic Products	717	742	773	838	766	541	683	767	801	853	754	774
Total	2661	2777	3059	3291	2858	2161	2646	2925	3118	3177	2641	2813
5-Year Average Demand ^c												
Building Construction			826.0					877.0				
Transportation			343.4					360.4				
Consumer and General Products			375.2					373.2				
Industrial Machinery and Equipment			538.2					534.4				
Electrical and Electronic Products			720.2					789.8				

^a1 Gigagram = 2.2 million pounds.^bPreliminary.^c(1972-1976, and 1977-1981).

due to the effects of stock changes and imports on fully fabricated copper products.

A look at the 5-year average demand shows that there has been an increase in three out of the five markets. The building industry market sales showed a gain of 6.2 percent. The transportation market shows a gain of 5.0 percent. An increase of 9.7 percent occurred in the electrical and electronic product markets. The demand for electrical equipment has risen because of increased emphasis on safety, comfort, recreation, and a pollution-free environment. Automation, including the use in computers, has also boosted the use of copper.

Substitution of other materials, coupled with the recession, has caused the slight drop of less than 1 percent in the consumer and general products markets. The 1 percent decline in the industrial machinery and equipment market is largely due to the impact of the recession.

The Bureau of Mines estimates that the most growth in copper demand will occur in the electrical and electronic products industries, consumer and general products, and building construction. Copper is an important metal in electric vehicles. If electric vehicles become popular, this would be a source of increased demand for copper. General Motors plans to produce an electric family car for mass marketing in the mid-1980's. A conventional internal combustion automobile contains from 6.8 to 20.4 kg of refined copper, whereas electric vehicles use much more copper. The Copper Development Association estimates range from 45.4 kg to 90.7 kg, with an average nearer to 45.4 kg.²¹

Another potential area for growth is in the solar energy industry. Presently, the extent of this sector is relatively modest, consuming approximately 4,500 Mg/yr of copper in the U.S. However, consumption in this sector has the potential to climb considerably.

In addition, the U.S. military demand for copper is expected to increase. Increased military expenditures will have a significant impact on copper demand because copper is an important element in modern electronic weaponry. During heavy rearmament periods the military demand for the metal has reached 18 percent of copper mill shipments. Although military demand is not expected to return to the record high 18 percent level, analysts do expect a large increase in military requirements for copper from the low level in 1979 of less than 2 percent.²²

The demand picture in the United States may receive a boost from the federal government. The government is committed to eventually acquire 1.1 gigagrams of copper for its currently depleted strategic stockpile. The previous stockpile was largely depleted in 1968; the final sale was in 1974 after copper prices had soared. Further Congressional action is necessary to implement and fund the purchase plan.

7.1.4.2 Substitutes. Substitutes for copper are readily available for most of copper's end uses. Copper's most competitive substitute is aluminum. Other competitive materials are stainless steel, zinc, and plastics. Aluminum, because of its high electrical conductivity, is used extensively as a copper substitute in high voltage electrical transmission wires. Aluminum has not been used as extensively in residential wiring because of use problems, and minimal savings.

Aluminum is also potentially a substitute for copper in many heat exchange applications. For example, automobile companies are still experimenting with the use of aluminum versus copper in car radiators. When copper prices are high, or copper supply is limited, cast iron and plastics are used in building construction as a copper pipe substitute. A relatively new substitute for copper is glass, which is used in fiber optics in the field of telecommunications.

7.1.5 Prices

Numerous factors influence the copper market, and thus the price of refined copper. These factors include: production costs, long-run return on investment, demand, scrap availability, imports, substitute materials, inventory levels, the difference between metal exchange prices and the refined price, and federal government actions (e.g., General Services Administration stockpiling and domestic price controls).

Among the many published copper price quotations, two key price levels are: 1) those quoted by the primary domestic copper producers and 2) those on the London Metal Exchange and reported in Metals Week, Metal Bulletin, and the Engineering and Mining Journal. The producers' price listed most often is for refined copper wirebar, f.o.b. refinery. The London Metal Exchange price,

referred to as LME, is also for copper sold as wirebar. The LME is generally considered a marginal price reflective of short-term supply-demand conditions, while the producer price is more long-term and stable and often lags the LME price movement.

Copper is also traded on the New York Commodity Exchange (Comex). Arbitrage keeps the LME price and the Comex price close together (with minor price differences due to different contract terms on the two exchanges, and a transportation differential).

Table 7-5 shows the LME, the U.S. producer price, and the U.S. producer price adjusted to a 1982 constant price for the years 1970 through 1982. Data were obtained from U.S. Bureau of Mines publications.

Several points can be observed from the table with respect to the LME price versus the U.S. producer price: (1) the LME price has had wider swings than the producer price; (2) in the past when both prices are relatively high, the LME price has been considerably higher than the producer price, while during relatively low price periods, the producer price has been moderately higher than the LME price; and (3) in recent years a marked change appears to be taking place away from a two-price system and toward a one-price system, with the difference between the LME and the U.S. producer price accounted for only by a transportation differential. These earlier situations had reoccurred repeatedly over the past 20 years. One other point about the table should be mentioned, although unrelated to the relationship of the LME to the producer price. The producer price has not kept pace with general inflation.

In theory, the U.S. producer price should be somewhat higher than the LME price since ocean transport costs must be incurred to get the refined copper to the U.S. However, this relationship appears to hold only during slack price periods. When LME prices are high, the producers do not raise their prices as much, which in theory appears contrary to profit maximization. Explanations offered for such behavior include: the producers' fear of long-run substitution for copper if the producers raised the price to the fabricators, high profits for integrated fabricators while reducing supply to nonintegrated fabricators, past fears of government stockpile sales that would reduce prices, and fear of the return of government intervention through price controls.

Table 7-5. AVERAGE ANNUAL COPPER PRICES^{23,24,25}
(cents per kg)^a

Year	LME ^b	U.S Producer Price ^c	U.S. Producer Price 1982 Constant Price ^d
1970	138.6	128.0	290.9
1971	106.7	114.4	248.7
1972	106.7	112.6	234.6
1973	178.0	130.9	256.7
1974	204.8	170.1	303.8
1975	123.4	141.2	231.5
1976	140.6	153.1	239.2
1977	130.7	147.0	216.2
1978	136.2	146.3	200.4
1979	198.2	205.3	259.9
1980	218.5	225.3	262.0
1981	174.7	187.2	199.1
1982 ^e	147.4	162.8	162.8

^aTo convert from cents/kg to cents/lb, multiply by 0.454.

^bLondon Metal Exchange "high-grade" contract.

^cU.S producer price, electrolytic wirebar copper, delivered U.S destinations basis.

^dAdjusted to 1982 constant price by applying implicit price deflator for gross national product (1972 = 100).

^ePreliminary.

The cost of producing copper is one of the elements that influences the price of copper. Considerable data exist to validate the point that the long-run economic cost of producing copper is increasing.²⁶ During the early 1970's the capital costs per megagram of annual capacity for developing copper from the mine through refining stage were \$2,000 to \$2,500, and by the late 1970's had risen sharply to \$7,200 to \$7,700. Estimates are that a price of \$2.76 per kg to \$3.30 per kg for refined copper would be needed to support such new capital outlays.

The above costs are for conventional pyrometallurgical smelting. The newer smelting processes such as Noranda and Mitsubishi offer some capital cost savings at that stage due to lower pollution control costs. The hydrometallurgical processes also require less capital. However, the mining costs are the highest part of overall development costs for which limited cost saving techniques exist. The mine development costs in the U.S. have risen significantly, largely as a result of the shifting from higher to lower grades of available copper ores and sometimes remote locations that require infrastructure costs for towns, roads, etc.

In 1979, the Bureau of Mines analyzed 73 domestic copper properties to determine the quantity of copper available from each deposit and the copper price required to provide each operation with 0 and 15 percent rates of return. The Bureau estimates that a copper price of \$4.56 per kg would be required if all properties, producing and nonproducing, were to at least break even. The average break-even copper price for properties producing in 1978, \$1.46 per kg, was about equivalent to the average selling price for the year. At this price, analysts calculate that only 25 properties could either produce at break-even or receive an operating profit. Of these properties, only 12 could receive at least a 15 percent rate of return.

Annual domestic copper production, from 1969 to 1978, averaged 1,337,000 megagrams. According to this study, in order to produce at this level and receive at least a 15 percent rate of return, a copper price of \$1.81 per kg is required. If the United States were to produce the additional 248,000 megagrams that were imported each year over this period, a copper price of \$1.94 would be necessary.²⁷ The report concludes that increases in copper prices are required in order for many domestic deposits to continue to produce.

It has been suggested that long-term potential for higher prices, plus the high cost of new capacity are significant reasons for the increased purchases several years ago of copper properties by oil companies. The reasoning is that oil companies need places for heavy cash flows, and diversification to other products is desirable. The oil companies reportedly can wait for expected copper price increases to obtain their return. Further, by purchasing existing facilities, rather than building new capacity, they avoid the escalating new capacity costs. However, more recently, some oil companies seems to be rethinking their investments in copper.

As shown below, U.S. oil (and gas) companies own or have major interests in many of the largest domestic copper producers:

1. Amax - Approximately 20 percent owned by Standard Oil of California
2. Anaconda - Owned by Atlantic Richfield Company (ARCO)
3. Cities Service - Also a primary copper producer
4. Copper Range - Owned by Louisiana Land and Exploration Company
5. Cyprus Pima Mining Company - Standard Oil Company (Indiana)
6. Duval - Owned by Pennzoil Company
7. Kennecott - Standard Oil of Ohio (British Petroleum)

These copper producers own or control a large portion of domestic copper reserves, mine production, and U.S. refinery capacity. Their investment in the copper industry is significant, and thus they must expect higher prices and substantial profits in the future.

7.2 ECONOMIC ANALYSIS

7.2.1 Introduction

This section presents the economic impact analysis of the arsenic NESHAP for the 14 low arsenic primary copper smelters. The fifteenth primary copper smelter is classified as a high arsenic smelter and is discussed in a separate analysis.

The principal economic impacts analyzed are: the ability of the smelters to increase copper prices in response to an increase in costs due to the arsenic standard; and, the impact on profits if part or all of the costs cannot be passed on in the form of price increases. Section 7.2.3 presents the methodology. Section 7.2.4 presents the impact on prices, Section 7.2.5 presents the impact on profits, and Section 7.2.6 presents a discussion of capital availability.

7.2.2 Summary

In 1982 the copper producers experienced one of the worst years in recent history. Such a situation cannot be used as the foundation to examine the long term economic impact of the potential arsenic NESHAP. Therefore the economic analysis is based on a more normal condition for the industry. However, even under more typical conditions for the industry, several smelters may face significant financial impairment.

If each smelter attempts to pass control costs forward in the form of a price increase, the price increases would range from 0 percent to 15.2 percent at a 80 percent capacity utilization rate, depending on the regulatory alternative. For Alternative II the price increase would be 0 for every smelter, with one exception that would have a 15.2 percent increase. For Alternative III the price increases would range from 0.1 percent to 6.3 percent. For Alternative IV the price increases are lower and would range from 0 to 1.3 percent. For Alternative III+IV the price increases would range from 0.1 percent to 7.6 percent. Competition will prevent the existence of such a broad variation.

If control costs are absorbed and profit margins reduced, again a broad range exists. At an 80 percent capacity utilization rate and a ten percent profit margin, for Alternative II the profit decrease would be 0 for every smelter, with one exception that would result in a net loss. For

Alternative III the profit decrease would range from 1.1 percent to 62.6 percent. For Alternative IV the profit decrease would be lower and would range from 0 percent to 12.8 percent. For Alternative III+IV the profit decrease would range from 1.1 percent to 75.4 percent.

Although the capital costs of the control equipment are not minor amounts, for most of the producers the capital cost would not present a major obstacle. For two of the producers the capital costs may present some difficulty.

7.2.3 Methodology

The purpose of this section is to explain in general terms the methodology used in the analysis. Each of the appropriate sub-sections explains the methodology in more detail. No single indicator is sufficient by itself to use for decision making purposes about the primary copper smelters. Therefore the methodology relies on several indicators which in total can be used to draw conclusions about the industry.

The methodology has three major parts. The first part is an analysis of price impacts. The analysis of price impacts introduces an upper limit on the problem and provides a benchmark to make evaluations on a relatively uncomplicated basis. A price increase represents the "worst case" from the viewpoint of a consumer of copper. The second major part of the methodology is an analysis of profit impacts. The analysis of profit impacts introduces a lower limit on the problem and is the "worst case" from the viewpoint of the firm. The individual characteristics of each smelter increase in importance and are incorporated to a greater extent. The third and final part is an analysis of the availability of capital to purchase the control equipment.

Firms in the copper industry face a wide variety of variables that in the aggregate determine the economic viability of the firm generally, and a smelter specifically. The variables can be grouped in four broad categories. The categories are described here separately and in a simplified manner for discussion purposes. However, there is a close interrelationship among the four categories and changes in one will have implications for the others. The four broad categories which encompass the variables that in turn determine the economic viability of the smelter are described below.

1) Macro-economic conditions. The two most prominent variables in this category are copper prices and copper demand. By-products and co-products represent a significant source of revenues for most copper operations. Therefore in addition to the price of copper, the price of by-products and co-products also influence an assessment of economic viability. Common by-products and co-products of copper production include: gold, silver, molybdenum, and sulfuric acid. Other by-products include selenium, tellurium, and antimony. For ease of presentation and in order to present a conservative analysis, by-products and co-products are not considered explicitly in the analysis. Another important variable, though, somewhat less visible, is government actions such as tax policy, stockpiling, and price controls. The government variable includes the U.S. Government, as well as foreign governments. For example, consider that a report by the U.S. Bureau of Mines has stated that at least 40 percent of the total mine production of copper in market economy countries was produced by firms in which various foreign governments owned an equity interest.²⁸

2) Environmental regulations. Since roughly 1970, environmental regulations have evolved to the point that they have become a major variable that must be considered in the corporate decision making process. Here again, government actions are important.

3) Corporate organizational strategy. This category includes the corporation's strategy with respect to variables such as remaining or becoming an integrated copper producer versus a non-integrated copper producer, or leaving the industry entirely.

Many of the companies that produce refined copper are integrated producers; that is, they own the facilities to treat copper during each of the four principal stages of processing: mining, milling, smelting, and refining. Also, several of the producers are integrated one additional step into the fabrication of refined copper. However, not all companies in the copper industry are integrated producers. There are companies that only mine and mill copper ore to produce copper concentrate, and then have the copper concentrate smelted and refined on a custom basis (the smelter takes ownership of the copper) or on a toll basis (the smelter charges a service fee and returns the copper to the owner). The existence of both integrated and non-integrated producers introduces a complex economic element into this

analysis. That complex economic element manifests itself in the choice of the appropriate profit center. This standard affects only one stage of the production process (smelting) in a direct way, but has indirect effects on the other stages.

For accounting purposes, integrated producers frequently view the smelter as a cost center, rather than a profit center. However, in an economic sense the smelter provides a distinct contribution to the production process that ultimately allows a profit to be earned although that profit may be realized for accounting purposes at another stage such as the mine or refinery.

4) Competition. Mines have long-run flexibility in deciding where they will send their copper concentrate for smelting. Therefore, copper smelters face competition from three sources: other existing domestic smelters, new smelters that may be built, and foreign smelters, especially Japanese. Other competition, though less direct, is also important. For example, scrap and substitutes present competition.

Japan is a major force among copper producing countries in terms of its volume of smelting, refining, and fabrication of copper. However, Japan does not have copper ore deposits of any noteworthy size. Therefore it must import concentrates in order to supply its smelting, refining, and fabricating facilities. Japan seeks concentrates from many countries, including the United States. Japan's ability to be competitive with domestic smelters for U.S. concentrates is indicated by the contractual arrangements it has established with Anamax and Anaconda to purchase concentrates. Also, the Japanese smelters have approached many other copper mine owners in the United States. For example, Cyprus Corporation is reported to have seriously considered shipping concentrates from its Bagdad mine to Japan.

The cost to transport concentrates across the Pacific Ocean is significant. The fact that Japanese smelters can compete with U.S. smelters, in spite of the costs to transport concentrates across the Pacific Ocean, is quite noteworthy. One factor that explains the Japanese ability to compete is that Japanese smelters are newer than U.S. smelters and, in theory, should be more cost competitive. Other factors that operate to the advantage of Japanese smelters, including a tariff mechanism, are described later.

The existence of competition for concentrates introduces what is commonly referred to as a "trigger" price. The "trigger" price is that price

which triggers or provides an economic incentive for the supplier of concentrate to change to another smelter and refinery. If a given smelter charges a service fee in excess of competing smelters, that smelter will lose business and eventually be forced to cease operations. In the case of new smelters or expansions, the new process facilities will not be built. Faced with an increase in costs, a smelter could respond using one of three options, or any combination of the three. First, the smelter could pass the costs forward in the form of a price increase. Two important considerations with respect to a price increase are: the prices of competitors in the copper business, and the elasticity of demand for the end users of copper. For example, even if all copper producers experience the same increase in costs, at some point the end users of copper will consider changing to a substitute. Second, the smelter could absorb the cost increase by reducing its profit margins, thereby reducing its return on investment (ROI). If the smelter's profit margins are reduced significantly it will cease operation. Third, the smelter could pass the costs back to the mines by reducing the price it is willing to pay for concentrate. An important consideration in setting the service fee a smelter charges for custom or toll smelting is that the concentrate may be shipped elsewhere, such as to Japan. Market conditions suggest that the option of passing costs back to the mines does not seem feasible at this time, due to the existence of excess smelting capacity.

7.2.3.1 Japanese Tariff mechanism. One example of foreign government assistance to the copper industry occurs in Japan. Japanese copper producers operate under a system that permits the payment of a premium for concentrates, which is then recovered through a premium for refined copper due to a protected internal market supported by a high tariff. Japan imposes high import duties on refined, unwrought copper while allowing concentrates to be shipped into the country duty-free. Duty on refined unwrought copper in 1981 was 8.2 percent of the value of the copper, including freight and insurance, as opposed to a U.S. customs duty of 1.3 percent of the value of copper. The import duties allow Japanese producers to sell their refined copper in Japan at an artificially high price and still remain competitive with foreign producers.

Specifically, copper concentrates and ore imported into Japan are free of duty. Refined copper imported into Japan is subjected to a tariff of

15,000 yen/Mg.²⁹ Using a December 15, 1980, exchange rate of \$0.004633/yen, the tariff was \$0.0849/kg. Refined copper may be duty-free under the preferential tariff, subject to certain limitations.

As a result of the tariff situation, Japanese copper producers can pay a premium to attract concentrates and can recover the premium through a premium on the price of the refined copper used in Japan. If the refined copper is returned to the customer outside of Japan, the premium on the price of refined copper is not recovered because world prices would prevail in this case, rather than the protected internal Japanese producer price. As a result, the principal interest of the Japanese copper producers is in producing copper for internal consumption. Toll smelting in Japan is generally used as a means of balancing inventories. The absence of a tariff on ore and concentrates encourages companies to import ore into Japan. The presence of a tariff on refined copper and the costs of holding metal in Japan discourage companies from importing refined copper into Japan.

The Japanese tariff on refined copper, combined with the cost of holding the metal until users have a demand for it, provides an extra margin for domestic copper producers. The Japanese producers can charge what the market will bear for their copper and still remain competitive with the importers. The loss incurred by Japanese producers in charging toll customers low processing rates is covered by the extra margin of profit realized by charging prices for domestic refined copper at competitive import levels.

Robert H. Lesemann (industry expert, formerly with Metals Week, now with Commodities Research Unit), in an affidavit for the Federal Trade Commission, outlined the situation in September 1979:

It is generally true that operating costs of U.S. smelters are the same as smelters in Japan, Korea, and Taiwan. The competitive advantage is without doubt due to the subsidies outlined above. Thus, while the terms of the Nippon-Amax deal have not been revealed, the treatment charge is likely well below the operating cost levels of U.S. smelters.³⁰

7.2.3.2 Other Japanese advantages. The tariff mechanism described above is one example of government assistance to the Japanese copper industry. Another example is provided by the Japanese government's approval of a brass

rod production cartel. In an effort to reduce stocks and boost profit margins for the ailing Japanese brass rod industry, the government approved the formation of a temporary cartel to cut production.³¹

Apart from government assistance, other reasons are cited for the advantage of the Japanese copper industry over the U.S. copper industry. Additional reasons include:

- A high debt-to-equity ratio--a typical Japanese smelter may have a debt-to-equity ratio of 0.8 to 0.9.^{32,33,34}
- Lower labor rates--Japanese hourly rates in the primary metals industry were estimated to be about two-thirds of the U.S. rate in 1978.³⁵
- By-product credits--the market for by-products, sulfuric acid, and gypsum is better in Japan than in the United States and reduces operating costs significantly.³⁶

7.2.4 Maximum Percent Price Increase

Insight into the economic impact of the arsenic NESHA can be gained by examining the maximum percentage copper price increase that would occur if all control costs were passed forward. A complete pass forward of control costs may not be possible in every case, and later in the analysis this assumption is relaxed. However, the initial assumption that a complete pass forward is possible in every case introduces a common reference point, which then facilitates comparisons of various control alternatives and scenarios.

The maximum percentage price increase is calculated using a simplified approach, for ease of presentation, that divides annualized control costs by the appropriate production and further divides that result by the refined price of copper, with the result expressed as the necessary percentage price increase per kilogram. The above approach does not consider the investment tax credit, and thus is a conservative approach that will tend to overstate the impact of the control costs. Other approaches could be used to determine price increases. For example, a net present value (NPV) approach could be

used. A net present value approach determines the revenue increases necessary to exactly offset the control costs, such that the NPV of the plant remains constant. An NPV analysis can also take into account the investment tax credit, depreciation over the applicable time period, income taxes, operating and maintenance costs, and the time value of money. Although the NPV approach is a more sophisticated calculation, the two approaches yield similar results. Therefore, the first method is preferable in this particular case due to its straightforward nature, ease of presentation, and reasonable results.

Table 7-6 shows the cost increase, and then Table 7-7 shows the maximum percentage price increase, of arsenic controls for low-arsenic primary copper smelters. The increase in the cost of production is shown for two capacity utilization rates, 100 percent and 80 percent. The advantage of presenting two capacity utilization rates is in the conduct of sensitivity analysis. A rate of 100 percent is optimistic, but is useful here as a reference point. A rate of 80 percent is more likely and as noted in Section 7.1 this is the approximate industry average utilization rate achieved in 1981. For 1982, the industry average capacity utilization rate was substantially lower at 59 percent. However, no analysis is shown here of the impact of control costs on the industry at a 59 or 60 percent utilization rate because regardless of control costs, a rate of 60 percent is damaging to the industry even as a baseline condition. Alternatives II, III, and IV are shown as well as the combination of III+IV. The smelters are ranked according to the cost of Alternative III+IV (with the exception of Kennecott-McGill). The purpose of showing the increase in production cost is to supplement the maximum percentage price increase. One advantage of reviewing the cost increase is that it is only dependent on the capacity utilization rate, and is not affected by the refined price of copper. A second advantage is that it is not affected by the choice of the profit center. Several points should be observed from the cost increases:

- 1) The amount of the cost increases are substantial for two of the smelters. The cost increases are substantial for several reasons. First, copper is a commodity, which means that product differentiation is not possible and thus competition is based almost exclusively on price. The copper producers can be characterized as price-takers and thus no individual producer controls the marketplace. Therefore, in an industry that competes based on price, the cost of production becomes exceptionally important.

Table 7-6. INCREASE IN COST OF PRODUCING COPPER DUE TO ARSENIC
CONTROLS FOR LOW-ARSENIC PRIMARY COPPER SMELTERS
(¢/kg.)

Smelter	Annual Capacity (Mg.)	100% Capacity Alternative				80% Capacity Alternative			
		II	III	IV	III+IV	II	III	IV	III+IV
ASARCO-Hayden	182,000	0	0.2	0	0.2	0	0.2	0	0.2
ASARCO-El Paso	91,000	0	0.3	0.2	0.5	0	0.4	0.2	0.6
Kennecott-Garfield	254,000	0	0.5	0.2	0.7	0	0.6	0.3	0.9
Phelps Dodge-Hidalgo	163,000	0	1.1	0.2	1.3	0	1.3	0.2	1.5
Phelps Dodge-Morenci	191,000	0	1.0	0.3	1.3	0	1.2	0.3	1.5
Inspiration	136,000	0	2.1	0.2	2.3	0	2.6	0.2	2.8
Magma	181,000	0	2.2	0.3	2.5	0	2.7	0.4	3.1
Phelps Dodge-Ajo	64,000	0	2.4	0.4	2.8	0	3.1	0.5	3.6
Phelps Dodge-Douglas	115,000	0	2.5	0.4	2.9	0	3.1	0.6	3.7
Copper Range-White Pine	52,000	0	2.5	0.5	3.0	0	3.1	0.6	3.7
Kennecott-Hayden	71,000	0	2.8	0.4	3.2	0	3.5	0.5	4.0
Kennecott-Hurley	73,000	0	3.7	0.4	4.1	0	4.6	0.5	5.1
Cities Service-Copperhill	13,600	0	9.4	1.9	11.3	0	11.7	2.4	14.1
Kennecott-McGill	45,000	22.7	6.0	0.6	6.6	28.4	7.5	0.7	8.2

Table 7-7. MAXIMUM PERCENT PRICE INCREASE FOR ARSENIC CONTROLS FOR LOW-ARSENIC PRIMARY COPPER SMELTERS

Smelter	187¢/kg. Price					220 ¢/kg. Price				
	100% Capacity Alternative		80% Capacity Alternative			100% Capacity Alternative		80% Capacity Alternative		
	II	III	IV	III+IV		II	III	IV	III+IV	
ASARCO-Hayden	0	0.1	0	0.1	0	0.1	0	0.1	0	0.1
ASARCO-El Paso	0	0.2	0.1	0.3	0	0.2	0.1	0.3	0	0.1
Kennecott-Garfield	0	0.3	0.1	0.4	0	0.3	0.2	0.5	0	0.2
Phelps Dodge-Hidalgo	0	0.6	0.1	0.7	0	0.7	0.1	0.8	0	0.3
Phelps Dodge-Morenci	0	0.5	0.2	0.7	0	0.6	0.2	0.8	0	0.3
Inspiration	0	1.1	0.1	1.2	0	1.4	0.1	1.5	0	0.6
Magma	0	1.2	0.2	1.4	0	1.4	0.2	1.6	0	0.1
Phelps Dodge-Ajo	0	1.3	0.2	1.5	0	1.3	0.3	1.6	0	1.2
Phelps Dodge-Douglas	0	1.3	0.2	1.5	0	1.7	0.3	2.0	0	0.2
Copper Range-White Pine	0	1.3	0.3	1.6	0	1.7	0.3	2.0	0	1.3
Kennecott-Hayden	0	1.5	0.2	1.7	0	1.9	0.3	2.2	0	1.4
Kennecott-Hurley	0	2.0	0.2	2.2	0	2.5	0.3	2.8	0	0.3
Cities Service-Copperhill	0	5.0	1.0	6.0	0	6.3	1.3	7.6	0	1.6
Kennecott-McGill	12.1	3.2	0.3	3.5	15.2	4.0	0.4	4.4	10.3	2.7
									3.0	12.9
									0.3	0.3
									3.7	3.7

Second, copper is traded on an international basis and thus domestic producers compete among themselves, as well as against foreign producers that may not experience the same cost increases. Finally, copper is faced with a significant threat from substitutes: such as, aluminum and plastic.

2) Within a single alternative, the differences among smelters are substantial. As described above, copper producers compete principally on price. As a result, the cost of production is quite important. Therefore differences in costs among smelters of as little as several cents are important.

3) The cost increases for Alternative II are 0 in every case with one exception, Kennecott-McGill. The cost increases for Alternative III range from a low of 0.2¢/kg to a high of 9.4¢/kg. The costs for Alternative IV are lower, and range from 0 to 1.9¢/kg. The costs for Alternative III+IV range from 0.2¢/kg to 11.3¢/kg.

Table 7-7 shows maximum percentage price increases. The purpose of reporting the maximum percentage price increase figures is to add perspective to the cost increase figures. Results are shown for two refined copper prices (187 cents per kg. and 220 cents per kg.), and for the same two capacity utilization rates presented earlier, 100 percent and 80 percent. The price increase assumes the firm is an integrated producer. The average annual price for refined copper over the past 5 years, from 1978 to 1982, has been approximately 187 cents per kg. The same cases are shown as were presented earlier for the cost increases, Alternatives II, III, IV and III+IV. The price of copper is difficult to predict, and therefore prudence suggests examination of a second price. As shown previously in Section 7.1, the highest average annual current dollar price for refined copper was 225.3 cents per kilogram, achieved in 1980. (The year 1980 was marked by an industry strike and reduced production.) Therefore, 220¢/kg is used to represent a price that based on the results of past years, appears optimistic. An alternative "pessimistic" price is not presented because even the baseline results are highly likely to be damaging and thus the addition of control costs would merely reinforce an obvious conclusion. A ready example of the impact of a price significantly below 187¢/kg was provided in 1982 when the average price was about 163¢/kg and large segments of the industry closed for sustained periods.

The analysis of the results for the maximum percentage price increase figures is similar to the analysis discussed above for the cost increase figures. Once again, for Alternative II only Kennecott-McGill experiences a price increase. The price increase is 12.1 percent based on a 100 percent capacity utilization rate and a price of 187¢/kg. For Alternative III the maximum price increases range from 0.1 to 5.0 percent. For Alternative IV the price increases are lower, and range from 0 to 1.0 percent. For Alternative III+IV the price increases range from 0.1 to 6.0 percent, with only two smelters above 2.2 percent. There is some variation in the price increases among the smelters. The significance of the variation in the maximum percentage price increases among the smelters is that those smelters with higher price increases would probably be constrained in the marketplace by the lower price increase smelters. As a result, some of the smelters could quite possibly have to absorb a part of the control costs. As mentioned above, two additional constraining influences are foreign competition and substitutes.

7.2.5 Profit Impacts

Apart from the calculation of maximum percentage price increase, additional insight into the economic impact of the arsenic NESHAP can be gained by making the opposite assumption from maximum percent price increase, that is, zero percent price increase, or complete cost absorption. The assumption of complete control cost absorption provides a measure of the reduction in profits if the control costs are absorbed completely.

Assuming control costs are absorbed, the critical element in an analysis of profit impacts is the profit margin. The larger a firm's profit margin, the greater is the firm's ability to absorb control costs and earn an acceptable rate of return on investment (ROI), and thus continue operation. The profit margin is simply the difference between price and cost. As mentioned in an earlier section, the central issue becomes the choice of an appropriate profit center and its corresponding price and cost. The processing of virgin ore into refined copper involves four distinct steps: mining, milling, smelting, and refining. Although the four steps are often joined to form an integrated business unit, they are not inextricably bound together in an economic sense. For example, it is not uncommon for mines to have their concentrate toll smelted and refined. The difficulty that this variability

presents in terms of an assessment of the impact of the arsenic standard is in the method of assigning the costs.

This report presents an analysis of profit impacts using two methods. The first method assumes copper producers are fully integrated and all have the same costs and thus earn a uniform profit margin. The objective of this method is to permit a ready, though simplified, examination of profit impacts. With the first method as a foundation, the second method introduces more smelter specific variables into the analysis in an effort to focus more sharply on the complex organizational structure of the industry.

7.2.5.1 Method One. As mentioned above, the critical element in an examination of profit impact is the profit margin. Therefore an examination of profit margins for members of the industry is necessary, and accordingly is presented below. Table 7-8 shows the revenues and operating profit (before tax) for each of the 7 producers for the 5-year period from 1977 to 1981. Table 7-8 also shows the percentage profit margin, which is operating profit divided by revenues. The revenue and operating profit figures are for the business segment within the company that includes copper. The use of business segment information provides a closer representation of the results for copper than would the use of the consolidated results for the company. The reason for this is that for several of the firms copper represents a relatively small share of the total company results. Although the business segment information is a better representation of the results for copper than the total company results, the business segments contain other products in addition to copper. Therefore conclusions must be drawn accordingly. The table shows that there is considerable variation in results, both within a company from one year to the next, as well as from one company to the next. The 5-year average ranges from a loss of 3.6 percent to a high of 13.8 percent.

Table 7-9 shows the maximum percentage reduction in the profit margin for each of the 14 smelters. This table assumes each smelter is viewed as part of a fully integrated operation. Two profit levels are shown and two capacity utilization rates (100 percent and 80 percent). The first profit level is based on a refined copper price of 187¢/kg and a 10 percent profit margin, which yields a profit of 18.7¢/kg. The second profit level

Table 7-8. BUSINESS SEGMENT RETURN ON SALES FOR COPPER COMPANIES^a
(\$ 10³)

	Year	ASARCO	Cities Service	Copper Range ^b	Inspiration	Kennecott	Magma ^c	Phelps Dodge
Revenues	1977	733,293	184,000	NA	95,676	NA	NA	453,184
	1978	849,002	241,500	64,600	101,251	683,000	274,137	446,970
	1979	1,339,917	276,300	89,300	136,849	1,091,400	381,512	618,188
	1980	1,440,220	224,100	83,900	178,004	987,400	287,581	714,591
	1981	1,153,022	NA	NA	NA	NA	328,842	706,404
Operating Profit ^d	1977	65,919	(38,600)	NA	(9,994)	NA	NA	52,831
	1978	112,474	(23,900)	(6,600)	(6,235)	(100)	13,601	63,738
	1979	225,763	25,400	10,000	9,889	164,000	67,252	159,428
	1980	145,286	16,300	1,800	(6,563)	131,400	11,522	95,439
	1981	68,364	NA	NA	NA	NA	(15,658)	27,618
Profit/ Revenues (percent)	1977	9.0	(21.0)	NA	(10.4)	NA	NA	11.7
	1978	13.2	(9.9)	(10.2)	(6.2)	NA	5.0	14.3
	1979	16.8	9.2	11.2	7.2	15.0	17.6	25.8
	1980	10.1	7.3	2.1	(3.7)	13.3	4.0	13.4
	1981	5.9	NA	NA	NA	NA	(4.8)	3.9
Average		11.0	(3.6)	1.0	(3.3)	9.4	5.5 ^e	13.8 ^f

^aBusiness segments contain other products in addition to copper.

^bThe Louisiana Land and Exploration Company.

^cProfit is net income after tax in this case.

^dBefore interest and tax.

^eWould yield 7.9 percent if adjusted to before tax with an effective tax rate of 30 percent.

^fImputed profit on intersegment sales for 1977 to 1981 would yield average return of 17.5 percent.

Table 7-9. MAXIMUM PERCENT PROFIT DECREASE FOR ARSENIC CONTROLS FOR LOW-ARSENIC PRIMARY COPPER SMELTERS

Smelter	18.7¢/kg. Profit Margin ^a										51.7 ¢/kg. Profit Margin ^b									
	100% Capacity Alternative					80% Capacity Alternative					100% Capacity Alternative					80% Capacity Alternative				
	II	III	IV	III+IV		II	III	IV	III+IV		II	III	IV	III+IV		II	III	IV	III+IV	
ASARCO-Hayden	0	1.1	0	1.1		0	1.1	0	1.1		0	0.4	0	0.4		0	0.4	0	0.4	
ASARCO-El Paso	0	1.6	1.1	2.7		0	2.1	1.1	3.2		0	0.6	0.4	1.0		0	0.8	0.4	1.2	
Kennecott-Garfield	0	2.7	1.1	3.7		0	3.2	1.6	4.8		0	1.0	0.4	1.4		0	1.2	0.6	1.8	
Phelps Dodge-Hidalgo	0	5.9	1.1	7.0		0	7.0	1.1	8.0		0	2.1	0.4	2.5		0	2.5	0.4	2.9	
Phelps Dodge-Morenci	0	5.3	1.6	7.0		0	6.4	1.6	8.0		0	1.9	0.6	2.5		0	2.3	0.6	2.9	
Inspiration	0	11.2	1.1	12.3		0	13.9	1.1	15.0		0	4.1	0.4	4.5		0	5.0	0.4	5.4	
Magma	0	11.8	1.6	13.4		0	14.4	2.1	16.6		0	4.3	0.6	4.9		0	5.2	0.8	6.0	
Phelps Dodge-Ajo	0	12.8	2.1	15.0		0	12.8	2.7	15.5		0	4.6	0.8	5.4		0	4.6	1.0	5.6	
Phelps Dodge-Douglas	0	13.4	2.1	15.5		0	16.6	3.2	19.8		0	4.8	0.8	5.6		0	6.0	1.2	7.2	
Copper Range-White Pine	0	13.4	2.7	16.0		0	16.6	3.2	19.8		0	4.8	1.0	5.8		0	6.0	1.2	7.2	
Kennecott-Hayden	0	15.0	2.1	17.1		0	18.7	2.7	21.4		0	5.4	0.8	6.2		0	6.8	1.0	7.8	
Kennecott-Hurley	0	19.8	2.1	21.9		0	24.6	2.7	27.3		0	7.2	0.8	8.0		0	8.9	1.0	9.9	
Cities Service-Copperhill	0	50.3	10.2	60.4		0	62.6	12.8	75.4		0	18.2	3.7	21.9		0	22.6	4.6	27.2	
Kennecott-McGill	121.4 ^c	32.1	3.2	35.3		151.9 ^c	40.1	3.7	43.8		43.9	11.6	1.2	12.8		54.9	14.5	1.4	15.9	

^aBased on a price of 187¢/kg and a 10 percent profit margin.

^bBased on a price of 220¢/kg and a 23.5 percent profit margin.

^cA 100 percent decrease in profit is a complete elimination of profit.

that costs increase by more than total profit, i.e., a loss occurs. A decrease of more than 100 percent means

is based on an increased price of refined copper to a level of 220¢/kg. The second profit margin is based on the original 18.7¢/kg. but adds the increase in price as extra profit while process costs are held constant. The second profit margin is 51.7¢/kg. Three considerations suggest the use of the second profit margin. The first consideration is the desirability of presenting sensitivity analysis in general. The second consideration is that a profit margin of 51.7¢/kg. based on a price of 220¢/kg. is a margin of 23.5 percent, which though clearly high, has been achieved within recent years by a member of the industry. Finally, because the margin is high, it in effect can be viewed as an upper limit, and thus any smelter that has a substantial profit impact in spite of such a favorable profit margin is in a very vulnerable position at a lower, more likely, profit margin.

The same cases discussed earlier are still applicable, the results are for Alternatives II, III, IV, and III+IV. At the first profit margin (18.7¢/kg.) the results show a maximum profit reduction of greater than 20 percent for 3 of the 14 smelters at the 100 percent capacity utilization rate for Alternative III+IV. At the 80 percent capacity utilization rate 4 smelters exceed 20 percent. For 2 of the above 4 smelters the profit reduction is greater than 40 percent at the 80 percent capacity utilization rate, and greater than 50 percent for 1 of the 2 smelters. Profit reductions of greater than 40 percent would seriously call into question the continued viability of these 2 smelters. At the second, higher, profit margin (51.7¢/kg.) the profit impacts are lessened substantially. Two smelters experience profit reductions of greater than 20 percent.

7.2.5.2 Method Two. Method two uses method one as a starting point and then refines it by relaxing the assumption of method one of an integrated producer and a uniform profit margin for all producers. Table 7-10 provides a means to identify those smelters that are most likely to face the greatest impact.

Table 7-10 starts by showing the smelters ranked according to the cost increase described earlier (Alternative III+IV). The size of the cost increase and the rank provides one indication of the potential impact of controls. A caveat that should be mentioned concerning this indicator is that it does not take into consideration baseline costs. Examination of baseline costs would be a useful supplement here. The 2 smelters with the highest cost increases are likely to experience serious difficulty due to the

Table 7-10. REVIEW OF SMELTERS

Smelter	Cost Increase rank - (¢/kg)	Major Capital Commitment	Major Integrated Mine	Closely Associated Refinery	Viability Estimates By Others (Reference #)
ASARCO-Hayden	1 0.2	1982	-	No	Viable-37
ASARCO-EI Paso	2 0.5	-	-	No	Viable-37
Kennecott-Garfield	3 0.7	1978	Yes	Yes	Viable-37
Phelps Dodge-Hidalgo	4 1.3	1976	-	No	Viable-37
Phelps Dodge-Morenci	5 1.3	1982	Yes	No	Viable-37
Inspiration	6 2.3	1980	-	Yes	Doubtful-38,37
Magma	7 2.5	-	Yes	Yes	Viable-37
Phelps Dodge-Ajo	8 2.8	-	-	No	Doubtful-38,37,39
Phelps Dodge-Douglas	9 2.9	-	No	No	Doubtful-38,16 Closure-37,39
Copper Range-White Pine	10 3.0	-	-	Yes	Viable-37
Kennecott-Hayden	11 3.2	-	Yes	Yes	Viable-37
Kennecott-Hurley	12 4.1	1982	Yes	Yes	Doubtful-37
Cities Service-Copperhill	13 11.3	-	-	No	Viable-37
Kennecott-McGill	14 6.6	-	No	No	Doubtful-38,37,16

costs. A second indicator that is presented to provide additional insight into a firm's possible reaction to control costs is a review of any major capital commitments to the smelter that a firm has made recently.

Most of the firms with the lower control cost increases have also recently made major capital commitments to their smelters which in turn suggests a stronger commitment than a firm that has postponed capital expenditures for a smelter. The third indication is provided by a review of whether or not the smelter has a major integrated mine that supplies much or all of its concentrates. The fourth indication is provided by a review of whether or not the smelter is closely associated with a refinery. Finally, the estimates of others who have analyzed the smelters are presented. The estimates are from four sources.

The above indications are useful but should be supplemented by two additional pieces of information. This information is noted below even though its impact has not been thoroughly analyzed at this time:

1) Newmont Mining Corp. recently purchased Cities Service Co.'s copper mine operations in Arizona (Pinto Valley). The concentrates from that mine currently go to the Inspiration smelter under a contract that runs until the end of 1984. These concentrates represent a significant share of Inspiration's production. The dollar value is approximately 15 percent of Inspiration's sales. After the contract expires these concentrates will then be processed at Newmont's Magma smelter. This will represent a significant loss for Inspiration and a significant gain for Magma.

2) Anaconda recently announced that it will close its Butte mine and no longer ship concentrates to Japan. At this time, it is not clear if the Japanese will seek replacement concentrates, and if so, what domestic mines are the most likely candidates to supply the concentrates.

7.2.6 Capital Availability

The principal determinant of the financial viability of a smelter is profitability. However, the amount of capital needed to purchase control equipment is one of the components that enters into an evaluation of profitability. Most firms prefer to finance pollution control equipment with debt, both because debt is less expensive than equity in general, and additionally because debt incurred to purchase pollution control equipment is often tax

exempt. Assuming control equipment is financed with debt, as the capital cost of the control equipment increases, the level of debt increases. An increased debt level means the fixed costs required to service the debt increase and therefore the level of risk increases. As a result, a discussion of capital availability will serve to supplement an assessment of profitability.

Table 7-11 shows the capital expenditures that will be necessary. The capital expenditures were explained in detail in an earlier section. The baseline capital expenditures are presented, as well as the capital expenditures for Alternatives II, III, and IV. Three firms own more than 1 smelter and in those 3 cases the total capital costs are shown, although the firms can make capital budgeting decisions on an individual smelter basis. The Tacoma smelter is in the high arsenic category but is included here to identify total capital costs to ASARCO. The capital costs for the smelters are not trivial sums. However, all of the 7 companies are major corporations. Additionally, 5 of the 7 companies are owned wholly, or to a substantial degree, by significantly larger parent corporations and thus are quite likely to have access to the necessary capital. The remaining 2 companies are ASARCO and Phelps Dodge.

For these 2 companies Table 7-11 shows the percent increase in long term debt if controls are added. The pre-control debt level is based on a 3-year average (1981 to 1979) debt level for each company. Controls are assumed to be financed totally with debt. The baseline percentage increase in debt is 24 percent for each company. An increase of 24 percent is substantial. For Alternatives II, III, and IV the incremental increases are generally moderate. In ASARCO's case the increases are 1, 2, and 1 percent respectively. In the case of Phelps Dodge the increases are 0, 5, and 1 percent, respectively. The capital costs associated solely with Alternatives II, III, and IV do not, in isolation suggest a major capital availability problem. However, the baseline increase taken together with the alternatives are considerable and may be a problem.

An additional indicator of capital availability is provided by the debt rating assigned to a company by one of the major national rating services. In 1982, as well as 1981 and 1980, ASARCO's debt was rated as A3 by Moody's.⁴⁰ This is an investment grade rating, but it is the lowest A rating. In 1982, the debt rating by Moody's for Phelps Dodge was lowered to Baa2 from its

Table 7-11. CAPITAL COSTS OF ARSENIC CONTROLS
FOR PRIMARY COPPER SMELTERS
(\$10³)

		Baseline	Alternative		
			II	III	IV
ASARCO	El Paso	46	0	1,375	370
	Hayden	75,606	0	1,702	0
	Tacoma		3,469	3,469	3,469
		<u>75,652</u>	<u>3,469</u>	<u>6,546</u>	<u>3,839</u>
	Debt Increase ^a	24%	1%	2%	1%
Cities Service	Copperhill	0	0	4,434	893
Copper Range	White Pine	0	0	4,434	893
Inspiration	Miami	0	0	9,825	922
Kennecott	Garfield	0	0	5,197	1,786
	Hayden	0	0	6,731	894
	Hurley	54,044	0	8,760	952
	McGill	0	10,530	8,760	893
		<u>54,044</u>	<u>10,530</u>	<u>29,448</u>	<u>4,525</u>
Newmont	Magma	0	0	13,050	1,786
Phelps Dodge	Ajo	51,067	0	6,731	894
	Douglas	0	0	9,825	1,787
	Hidalgo	0	0	6,731	894
	Morenci	95,294	0	8,526	1,786
		<u>146,361</u>	<u>0</u>	<u>31,813</u>	<u>5,361</u>
Debt Increase ^a		24%	0%	5%	1%

^aPercent increase in average long term debt level for the past 3 years (1981 to 1979) if controls are added as debt.

previous rating in 1980 and 1981 of A. Although Baa2 is still a relatively strong rating, the fact that it was lowered from 1981 to 1982 suggests that substantial increases in the amount of debt held by the company may present some difficulties.

7.3 SOCIO-ECONOMIC IMPACT ASSESSMENT

7.3.1 Executive Order 12291

The purpose of Section 7.3.1 is to address those tests of macro-economic impact as presented in Executive Order 12291, and, more generally, to assess any other significant macroeconomic impacts that may result from the NESHAP. Executive Order 12291 stipulates as "major rules" those that are projected to have any of the following impacts:

- An annual effect on the economy of \$100 million or more.
- A major increase in costs or prices for consumers; individual industries; Federal, State, or local government agencies; or geographic regions.
- Significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of U.S.-based enterprises to compete with foreign-based enterprises in domestic or export markets.

7.3.1.1 Annualized Control Costs. The annualized control costs for each of the 3 alternatives is well below the \$100 million which is the figure used to identify a major rule. The annualized control costs for Alternatives II, III, IV, and III+IV are \$10.2 million, \$26.8 million, \$4.3 million, and \$31.1 million, respectively.

7.3.1.2 Regional Effects, Employment and Competition. Most of the copper smelters are located in the Southwestern United States, and in particular, 7 smelters are located in Arizona. As a result, economic impacts would be concentrated in that geographical area. A copper smelter typically employs about 500 people.

The domestic copper producers compete among themselves, as well as against foreign copper producers and substitutes. Any substantial increase

in costs will put pressure on the competitive position of some domestic smelters with respect to other domestic smelters, and also with respect to foreign copper producers, and substitutes.

7.3.2 Regulatory Flexibility

The Regulatory Flexibility Act of 1980 (RFA) requires that differential impacts of Federal regulations upon small business be identified and analyzed. The RFA stipulates that an analysis is required if a substantial number of small businesses will experience significant impacts. Both measures must be met, substantial numbers of small businesses and significant impacts, to require an analysis. If either measure is not met then no analysis is required. The EPA definition of a substantial number of small businesses in an industry is 20 percent. The EPA definition of significant impact involves three tests, as follows: one, prices for small entities rise 5 percent or more, assuming costs are not passed onto consumers; or two, annualized investment costs for pollution control are greater than 20 percent of total capital spending; or three, costs as a percent of sales for small entities are 10 percent greater than costs as a percent of sales for large entities.

The Small Business Administration (SBA) definition of a small business for Standard Industrial Classification (SIC) Code 3331, Primary smelting and refining of copper is 1,000 employees. Table 7-12 shows recent employment levels for each of the 7 companies that own primary copper smelters. All 7 have more than 1,000 employees. Therefore, none of the 7 companies meets the SBA definition of a small business and thus no regulatory flexibility analysis is required.

Table 7-12. NUMBER OF EMPLOYEES AT COMPANIES
THAT OWN PRIMARY COPPER SMELTERS

Company	Employees	Source ^a
ASARCO, Inc.	12,700	1980 SEC 10-K p. A7
Cities Service Co.	18,900	1980 SEC 10-K p. 6
Copper Range Co. ^b	3,049	1980 SEC 10-K p. 22
Inspiration Consolidated Copper Co.	2,180	1980 SEC 10-K p. 2
Kennecott Corp. ^c	35,000	1980 SEC 10-K p. 10
Newmont Mining Corp.	12,400	1980 SEC 10-K p. 9
Phelps Dodge Corp.	15,220	1980 SEC 10-K p. 1

^aSEC 10-K is Securities and Exchange Commission, Form 10-K.

^bCopper Range Co. is a wholly-owned subsidiary of the Louisiana Land and Exploration Company. Figures are for Louisiana Land and Exploration.

^cPrior to merger with Sohio on March 12, 1981.

7.4 References

1. Review of New Source Performance Standards for Primary Copper Smelters -- Background Information Document, Preliminary Draft. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. Publication No. EPA-February 1983. p. 3-2.
2. ASARCO, Inc., Form 10-K. December 31, 1980. p. A2.
3. Cities Service Co., Annual Report 1980. p. 41.
4. The Louisiana Land Exploration Co., Form 10-K. December 31, 1980. p. 16.
5. Inspiration Consolidated Copper Company, Annual Report 1980. p. 2.
6. Kennecott Corp., Form 10-K. December 31, 1980. p. 4.
7. Newmont Mining Corp., Form 10-K. December 31, 1980. p. 3.
8. Phelps Dodge Corp., Form 10-K. December 31, 1980. p. 2, 4.
9. Buttermann, W.C. U.S. Bureau of Mines. Preprint from the 1981 Bureau of Mines Minerals Yearbook. Copper. p. 3.
10. Buttermann, W.C. U.S. Bureau of Mines. Mineral Industry Surveys. Copper Production in December 1982. p. 2.
11. Schroeder, H. J. and James A. Jolly. U.S. Bureau of Mines. Preprint from Bulletin 671. Copper - A Chapter from Mineral Facts and Problems, 1980 Edition. p. 14-16.
12. Annual Data 1982. Copper Supply and Consumption. Copper Development Association Inc. New York, New York. p. 6, 14.
13. Reference 11, p. 5.
14. Reference 9, p. 1.
15. Reference 9, p. 5.
16. Arthur D. Little, Inc. Economic Impact of Environmental Regulations on the United States Copper Industry. U.S. EPA. January 1978. p. V-8.
17. Reference 9, p. 24-29.

18. Reference 12, p. 14.
19. Reference 11, p. 14.
20. Reference 12, p. 18.
21. Copper's Hope: Electric Vehicles. Copper Studies. Commodities Research Unit, Ltd. New York. March 30, 1979, p. 5.
22. Copper in Military Uses. Copper Studies. Commodities Research Unit, Ltd. New York, February 15, 1980. p. 1.
23. Buttermann, W.C. U.S. Bureau of Mines. Mineral Industry Surveys. Copper in 1982 - Annual, Preliminary. p. 2.
24. Buttermann, W.C. U.S. Bureau of Mines. Preprint from the 1980 Bureau of Mines Minerals Yearbook. Copper. p. 1.
25. Schroeder, H. J., and G. J. Coakley. U.S. Bureau of Mines Preprint from the 1975 Minerals Yearbook. Copper. p. 2.
26. The Capital Cost Picture. Copper Studies. Commodities Research Unit, Ltd. New York. August 18, 1975. p. 1.
27. Rosenkranz, R.D., R.L. Davidoff, and J.F. Lemons, Jr., Copper Availability-Domestic: A Minerals Availability System Appraisal. U.S. Bureau of Mines. 1979. p. 13.
28. Sousa, Louis J. U.S. Bureau of Mines. The U.S. Copper Industry: Problems, Issues, and Outlook. Washington, D.C. October, 1981. p. 67.
29. Copper Imports on Preferential Tariff. Japan Metal Journal (Tokyo). December 8, 1980. p. 3.
30. Affidavit of Robert J. Leemann, Commodities Research Unit/CRI and former editor-in-chief of Metals Week, to the Federal Trade Commission. September 27, 1979. FTC Docket Number 9089.
31. Brass Rod Production Cartel Starts. Japan Metal Journal (Tokyo). July 6, 1981. p. 1.
32. Smelter Pollution Abatement: How the Japanese Do It. Engineering and Mining Journal. May 1981. p. 72.
33. Rieber, Michael. Smelter Emission Controls: The Impact on Mining and The Market For Acid. University of Arizona, Tucson, Arizona. March, 1982. p. 5-10.
34. Custom Copper Concentrates. Engineering and Mining Journal. May 1982. p. 73.

35. Everest Consulting Associates, Inc., and CRU Consultants, Inc. The International Competitiveness of the U.S. Nonferrous Smelting Industry and the Clean Air Act. Princeton, NJ. April 1982. p. 9-9.
36. Reference 32.
37. Reference 33, p. 1-11.
38. Everest Consulting Associates, Inc. The International Competitiveness of the U.S. Non-Ferrous Smelting Industry and the Clean Air Act. Princeton, N.J. April 1982. p. 3-17.
39. Phelps Dodge Corp. 1981 Annual Report. p. 8.
40. Moody's Industrial Manual 1982 Vol. I, p. 58, Vol. II, p. 4236.

APPENDIX A

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

<u>Date</u>	<u>Activity</u>
July 13-14, 1976	Emission source testing at Phelps Dodge Copper Smelter, Ajo, Arizona.
December 10-16, 1976	Emission source testing at Kennecott Copper Smelter, Hayden, Arizona.
April 18-26, 1977	Emission source testing at Anaconda Copper Smelter, Anaconda, Montana.
June 20-30, 1977	Emission source testing at ASARCO Copper Smelter, El Paso, Texas.
January 17-27, 1978	Emission source testing at ASARCO Copper Smelter, El Paso, Texas.
May 1-5, 1978	Emission source testing at Phelps Dodge Copper Smelter, Douglas, Arizona.
May 10-12, 1978	Emission source testing at Phelps Dodge Copper Smelter, Ajo, Arizona.
June 12-16, 1978	Emission source testing at Phelps Dodge Copper Smelter, Ajo, Arizona.
July 11-12, 1978	NAPCTAC Meeting in Raleigh, North Carolina to discuss issues related to development of arsenic emission standards for primary copper smelters.
July 24-27, 1978	Emission source testing at Phelps Dodge Copper Smelter, Hidalgo, Arizona.
September 12-25, 1978	Emission source testing at ASARCO Copper Smelter, Tacoma, Washington.
October 30 - November 15, 1978	Emission source testing at Kennecott Copper Smelter, Garfield, Utah.

<u>Date</u>	<u>Activity</u>
May 8-15, 1979	Emission source testing at ASARCO Copper Smelter, Tacoma, Washington.
July 23-24, 1979	Emission source testing at Phelps Dodge Copper Smelter, Ajo, Arizona.
September 10-16, 1979	Emission source testing at Phelps Dodge Copper Smelter, Morenci, Arizona.
September 18-22, 1979	Emission source testing at Phelps Dodge Copper Smelter, Douglas, Arizona.
December 7-13, 1979	Emission source testing at Kennecott Copper Smelter, McGill, Nevada.
March 11-13, 1980	Plant visit to Hibi Kyodo Copper Smelter, Tamano, Japan, to collect information on the fugitive emissions control system.
April 14-23, 1980	Emission source testing at Magma Copper Smelter, San Manuel, Arizona.
June 5, 1980	EPA listing of inorganic arsenic as a hazardous pollutant under Section 112 of the Clean Air Act.
June 24-26, 1980	Plant visit and emission source testing at ASARCO Copper Smelter, Tacoma, Washington.
March 17, 1981	NAPCTAC meeting in Raleigh, North Carolina to discuss regulatory alternatives for limiting arsenic emissions from low-arsenic throughput primary copper smelters.
January 12, 1983	Judicial Opinion and Order, filed with United States District Court, Southern District of New York, pertinent to action brought by State of New York against EPA Administrator (New York v. Gorsuch, ___ F. Supp. ___ (S.D.N.Y. 1983)). Order for EPA to propose emission standards for inorganic arsenic within 180 days of Order.
January 14-22, 1983	Emission source testing at ASARCO Copper Smelter, Tacoma, Washington.
April 27, 1983	NAPCTAC meeting in Raleigh, North Carolina, to discuss general approach and EPA staff recommendations for setting standards for inorganic arsenic emissions from primary copper smelters.

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system which is cross indexed with the October 21, 1974, Federal Register (39 FR 37419) containing the Agency guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing
Regulatory Action Environmental
Impact Statements (39 FR 37419)

Location Within the Background
Information Document (BID)

1. Background and Description

Summary of the Regulatory
Alternatives

The regulatory alternatives are
summarized in Section 1.2.

Statutory Authority

Statutory authority is cited in
Section 1.1.

Industry Affected

A description of the industry
to be affected is given in
Section 7.1.

Sources Affected

Descriptions of the various
sources to be affected are
given in Section 2.0.

Availability of Control
Technology

Information on the availability
of control technology is given
in Section 3.0.

2. Regulatory Alternatives

Regulatory Alternative I --
No Action (Baseline)

Environmental Impacts

Environmental effects of Regulatory
Alternative I are considered in
Section 5.0.

Costs

Costs associated with Regulatory
Alternative I are considered in
Section 6.0.

Regulatory Alternative II --

Environmental Impacts

Environmental effects associated
with Regulatory Alternative II
emission control systems are
considered in Section 5.0.

Costs

The cost impact of Regulatory
Alternative II emission control
systems is considered in
Section 6.0.

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (Concluded)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
Regulatory Alternative III --	
Environmental Impacts	The environmental effects associated with Regulatory Alternative III emission control systems are considered in Section 5.0.
Costs	The cost impact of Regulatory Alternative III emission control systems is considered in Section 6.0.
Regulatory Alternative IV	
Environmental Impacts	The environmental effects associated with Regulatory Alternative IV emission control systems are considered in Section 5.0.
Costs	The cost impact of Regulatory Alternative IV emission control systems is considered in Section 6.0.
Regulatory Alternative V	
Environmental Impacts	The implementation of this alternative would require the elimination of inorganic arsenic emissions at low-arsenic throughput primary copper smelters. Inorganic arsenic emissions would be zero.
Costs	This alternative could not be implemented without closing all plants in the source category. This was not considered reasonable and hence costs were not evaluated.

APPENDIX C

SUMMARY OF TEST DATA

SUMMARY OF TEST DATA

An emission test program was undertaken by EPA to evaluate the performance of alternative control techniques available for the control of process and fugitive arsenic emissions from process facilities including roasters, smelting furnaces, and converters at primary copper smelters. This appendix presents a brief description of the process facilities and control equipment tested, and a summary of the results obtained.

Arsenic emission measurements were conducted at eight domestic smelters. Particulate emission measurements were also conducted at some of these smelters. A listing of the process facilities and air pollution control equipment tested and the emission measurements conducted is presented in Table C-1. All arsenic measurements were performed using EPA Method 108, the recommended EPA method for the determination of arsenic from stationary sources. Measurements of total particulate were performed in accordance with EPA Method 5.

In addition to the arsenic and particulate emission measurements, visible emission observations were recorded at one of the above eight domestic smelters, ASARCO-Tacoma, and one other smelter located in Japan, the Tamano smelter.

A brief description of each smelter, as well as the process and control device tested, is presented in Sections C.1 through C.9. Section C.10 contains the data tables from the emissions measurement and opacity observation tests.

C.1 ASARCO-TACOMA

The ASARCO smelter at Tacoma, Washington, is a custom smelter which processes copper ore concentrates, precipitates, and smelter

by-products from numerous domestic and foreign sources. The smelter produces about 320 Mg (352 tons) of anode copper per day at full smelt and houses the only arsenic production facility in the United States. Copper smelter facilities include 10 roasters (6 Herreschoff multi-hearth roasters and 4 C&W Roasters), 2 reverberatory smelting furnaces, 4 Pierce-Smith converters, 3 anode furnaces (1 hearth type furnace and 3 tilting type furnaces),* and an electrolytic refinery.** Arsenic production facilities consist of three Godfrey roasters, arsenic trioxide settling chambers or kitchens, storage facilities, and a metallic arsenic plant.

The roaster charge which consists of a blend of concentrates, precipitates, lead speiss, flue dust, and fluxing materials typically contains 3 to 4 percent arsenic and 7 to 10 percent moisture. At full smelt, four to five roasters are used. Charging is continuous. The calcine produced, about 45.4 Mg (50 tons) per hour, is intermittently discharged from hoppers located below the roasters into larry cars for transport to one of two reverberatory furnaces. Typically, two 5.9 Mg (6.5 ton) cars are charged every 15 minutes. Fugitive emissions which could escape are confined and captured by close-fitting exhaust hoods located at the discharge point and are vented into the main roaster flue by two $73.6 \text{ Nm}^3/\text{min}$ (2,600 scfm) fans. In addition, general ventilation is applied at the south end of the larry car tunnel to control fugitive emissions resulting from the re-entrainment of settled dust within the tunnel.

Offgases from the roasters, which average about $3,570 \text{ m}^3/\text{min}$ (126,000 acfm) at 260°C (500°F), are combined with the exhaust gases from the ancillary fugitive emission control systems [$850 \text{ Nm}^3/\text{min}$ (30,000 scfm)] and reduced in temperature to less than 120°C (250°F). The total gases are then treated in a baghouse for particulate removal. The baghouse consists of 17 compartments containing 120 bags each. The bags are made of acrylic and measure 20.3 cm (8 inches) in diameter and 7.6 meters (25 feet) in length. The total baghouse filtering area

* Starting September 1978 only the two tilting furnaces are being used; the hearth type furnace is no longer used.

**Operation of electrolytic refinery was discontinued in January 1979.

is $9,950 \text{ m}^2$ ($107,100 \text{ ft}^2$). The baghouse is designed to effectively treat $5,664 \text{ m}^3/\text{min}$ ($200,000 \text{ acfm}$) of gas at an air-to-cloth ratio of about 1.9 to 1.0. Bag cleaning is performed by mechanical shakers. The clean baghouse exhaust is vented through a flue to the smelter main stack.

Although the smelter has two reverberatory smelting furnaces, each with an approximate smelting capacity of 1,090 Mg (1,200 tons) per day, the designated Number 2 furnace is used almost exclusively. The furnace measures 33.5 m (110 feet) in length and 9.8 m (32 feet) in width and is fired by either oil or natural gas. Furnace charging is accomplished by discharging the larry cars through one of four Wagstaff guns located along the furnace sidewalls. Typically, it takes less than 1 minute to discharge each car. At full smelt, two cars are discharged about every 15 minutes. To minimize potential fugitive emissions during charging, a manual control override is used which simultaneously opens the furnace flue control damper and reduces the fuel supply to the furnace fire prior to each charge to prevent pressure surges in the furnace.

Matte is tapped from the furnace as required by converter operations through one of four tapping ports. Only one tapping port is used at a time. The matte flows through a cast copper launder to a 4.25 m^3 (150 ft^3) cast steel ladle for transfer to the converters. At full smelt, about 45 ladles are transferred per day. It takes about 7 minutes to fill one ladle. Similarly, slag is skimmed through one of two tapping ports as required to maintain the proper slag level in the furnace and transferred to a 5-pot slag train for transit to the slag dump. Once tapped, the slag flows through a cast steel launder and into a 2.8 m^3 (100 ft^3) cast steel slag pot. At full smelt, about 20 five-pot slag trains are dumped per day. Each train takes about 15 minutes to fill. Fugitive emissions generated during both matte and slag tapping operations are controlled by local ventilation techniques. Tapping ports, launders, and launder-to-ladle/pot transfer points are hooded and ventilated. Ventilation requirements for the matte tapping system total about $700 \text{ m}^3/\text{min}$ ($25,000 \text{ acfm}$), while the ventilation requirements for the slag skimming system total about $600 \text{ m}^3/\text{min}$.

(21,000 acfm). Captured emissions from both systems are currently controlled by an electrostatic precipitator prior to venting from a stack to the atmosphere.

Process gases from the reverberatory furnace, which average about $1,415 \text{ Nm}^3/\text{min}$ (50,000 scfm), pass through a pair of waste heat boilers where the gases are cooled to about 400°C (750°F). The exiting gases then pass through a large rectangular brick flue where additional cooling and gas stream conditioning is provided by air infiltration and water and sulfuric acid sprays located in the flue. The resultant gas stream, about $6,100 \text{ actual m}^3/\text{min}$ (215,000 acfm) at 132°C (270°F), then enters the first of two electrostatic precipitators in series for particulate removal. The first precipitator is a tube or pipe design consisting of 18 sections with a total collection area of about $6,619 \text{ m}^2$ ($71,250 \text{ ft}^2$). Each section contains 84 pipes measuring 30.5 cm (12 inches) in diameter and 4.6 m (15 feet) in length. The second unit is a plate type design. It consists of seven parallel chambers each with four fields in series and has a total collection area of $7,710 \text{ m}^2$ ($82,992 \text{ ft}^2$). The exiting gases, about $7,740 \text{ actual m}^3/\text{min}$ (270,000 acfm) at 110°C (230°F), are discharged through a large flue to the smelter main stack.

Matte from the reverberatory furnace is transferred to one of four Pierce-Smith converters. Three of the converters measure 4.0 m (13 feet) in diameter by 9.1 m (30 feet) in length, while the fourth converter is 3.4 m (11 feet) in diameter and 7.9 m (26 feet) long. In addition to copper matte, smelter reverts and cold dope materials are also processed. Typically, only two converters are on blow at any one time. A converter cycle normally takes from 10 to 12 hours. With dilution air, the offgas flow per blowing converter is about $1,130 \text{ Nm}^3/\text{min}$ (40,000 scfm) and contains from 3 to 4 percent SO_2 . Blister copper produced is transferred to one of three anode furnaces for refining and casting. The slag skimmed from the converters is recycled to the reverberatory furnace.

Offgases from converter blowing operations are captured by water-cooled hoods and pass through a series of multiclones and a settling flue for coarse particulate removal prior to entering the gas cleaning circuits of either a liquid SO_2 plant or single-contact

sulfuric acid plant. The gas cleaning circuits for both plants are similar and consist of a water spray chamber, electrostatic precipitator, scrubbers, and mist precipitators in series. The single-contact acid plant has a 182 Mg/day (200 TPD) capacity at 5 percent SO_2 and is capable of processing $652 \text{ Nm}^3/\text{min}$ (23,000 scfm) of converter gas. The liquid SO_2 plant processes up to $12,748 \text{ Nm}^3/\text{min}$ (45,000 scfm) of the converter gases. The plant uses dimethylaniline (DMA) to absorb the SO_2 in the gas stream and uses steam stripping from regeneration. The 100 percent concentrated SO_2 gas stream produced is then liquified by compression and the liquid SO_2 stored.

Inlet and outlet emission measurements for arsenic were conducted by EPA across the roaster baghouse and the arsenic baghouse (metallic and kitchen) on September 12 through September 25, 1978. Arsenic test results are summarized in Tables C-3 through C-7.

Testing for arsenic was also conducted on September 15, 16, and 18, 1978, at the outlet of the reverberatory furnace ESP. These results are shown in Table C-8.

Tests were also conducted for roaster calcine discharge, matte tapping, slag tapping, and converter slag return. Data obtained for these sources are presented in Tables C-9 through C-12.

Visible emission observations were made by using EPA Method 22 and EPA Method 9 for calcine loading of larry cars, matte tapping, slag tapping, and converter slag return on June 24-26, 1980. Tables C-65 through C-73 present the results of these visible emissions observations.

C.2 ASARCO-EL PASO

The ASARCO smelter at El Paso is a custom smelter that processes copper ore concentrates from numerous sources. The smelter produces about 315 Mg (350 tons) of anode copper per day. Copper smelting facilities consist of ore handling and bedding facilities, four multi-hearth roasters, one reverberatory smelting furnace, and three Pierce-Smith converters. In addition, this smelter also has separate process facilities for zinc and lead production.

The smelter feed, consisting of a blend of concentrates, precipitates, lime and flue dust, and typically containing more than 0.2 percent

arsenic, is charged to four Herreshoff multi-hearth roasters. Each roaster has seven hearths and is capable of producing approximately 356 Mg (392 tons) of calcine per day. The calcine is taken by larry car to the single reverberatory furnace which is 90 cm (35.7 in.) long and 20 cm (8.0 in.) wide and fired with either oil or natural gas. The furnace is charged by Wagstaff guns located along the furnace side walls. The matte is tapped from one of five tap holes located on the north and south sides of the furnace. Slag is tapped from the west side of the furnace and is disposed of in a slag dump.

Matte from the furnace is transported to one of three Pierce-Smith converters. Each of the converters is 4 m in diameter and 9 m long. Normally, two converters are in the blowing mode at one time. In addition to copper matte, flue dust and cold dope materials, converters also process lead matte from the adjacent lead smelter when available. Blowing time generally ranges from 10 to 12 hours. Blister copper produced is further refined in two anode furnaces and then cast into anodes for shipment.

Offgases from the reverberatory furnace, which average about $1,700 \text{ Nm}^3/\text{min}$ (60,000 scfm), pass through a pair of waste heat boilers where the gases are cooled to about 400°C (750°F) and about 23 Mg (50,000 lb) of steam is produced. The gases exit the waste heat boilers through two parallel ducts and are then combined with the roaster offgases in a main flue. The combined gas stream, consisting of about $5,000 \text{ Nm}^3/\text{min}$ (177,000 scfm) at 200°C (400°F), then passes through a spray chamber where it is cooled to about 110°C (230°F) prior to entering an electrostatic precipitator for particulate removal. The precipitator consists of seven parallel chambers. Each chamber has four fields in series and has a total field volume of 535 m^3 ($18,900 \text{ ft}^3$). Gases exiting the precipitator are discharged to the main stack through a large balloon flue.

Offgases from the converter blowing operations average $6,000 \text{ Nm}^3/\text{min}$ (56,500 scfm). They then pass through a settling chamber, two waste heat boilers, and a spray chamber where the gases are cooled from 315°C (600°F) to 110°C (230°F). This process occurs prior to treatment in an electrostatic precipitator for particulates.

The precipitator consists of four parallel chambers, each of which has four fields in series. The exiting offgases then pass through a venturi scrubber for additional particulate removal, are humidified and cooled in a pair of packed-bed scrubbers, and are treated in a series of mist precipitators where acid mist and any remaining particulates are removed prior to entering a double-contact acid plant for SO_2 removal. The acid plant has a normal production rate of 408 Mg (450 tons) of acid per day. Either 93 or 98 percent sulfuric acid is produced. The acid plant tail gas streams are discharged through a 30.5 m (100 ft) stack.

Emission measurements were conducted by EPA during June 26-30, 1977. Inlet and outlet arsenic and mass measurements were made across the roaster/reverberatory electrostatic precipitator. Three inlet locations and one outlet location were sampled. The inlet locations included a large downtake duct off of the multi-hearth roasters, and two parallel ducts downstream of the reverberatory waste heat boilers. The outlet location consisted of the balloon flue downstream of the precipitator. Three arsenic and two total particulate runs were conducted. The arsenic and particulate test results are summarized in Tables C-13 through C-22, and Table C-29.

Arsenic emission tests were also conducted across the double-contact sulfuric acid plant. Three inlet and outlet measurements were made. The sampling locations included a duct upstream of the spray chamber/ESP and the acid plant tail gas stack. The results of these tests are summarized in Tables C-23 and C-24. Process conditions were carefully observed, and testing was conducted only when the subject process facilities and control equipment were operating within normal operating limits.

Fugitive emissions from the reverberatory furnace matte tapping operation at ASARCO-El Paso are captured by hoods over the ladle, covered matte launders, and a hood at the matte tapping holes. Gases from these sources are combined in a common duct and directed through a fan to a baghouse. The baghouse discharges into the roaster/reverberatory spray chamber/ESP control system which discharges from the 250 m (828 ft) main stack.

Fugitive gases that escape the converters during the blow period, and roll-in/out operations and other fugitive gases in the converter building, are collected at the roof of the converter building. Collected fugitive gases are drawn through four openings at the roof into ducts that combine into a main duct leading to a baghouse, through fans on the clean side of the baghouse, and then out the 250 m (828 ft) main stack.

The fugitive gas flow through the baghouse averages $14,100 \text{ Nm}^3/\text{min}$ (498,000 scfm). The converter building fugitive baghouse consists of 12 compartments. Normally all compartments are in operation except one compartment which is taken off during the cleaning cycle and another compartment which is taken off for maintenance purposes for a fraction of the total time. Each of the 12 compartments contains 384 Orlon or Dacron bags. Each compartment is 20 cm (8 in.) in diameter, 6.7 m (22 ft) long, with a cloth area of $1,644 \text{ m}^2$ ($17,700 \text{ ft}^2$) per compartment. The total net cloth area of the baghouse is about $19,700 \text{ m}^2$ ($212,400 \text{ ft}^2$). The baghouse was designed to effectively treat $15,282 \text{ actual m}^3/\text{min}$ (540,000 acfm) at 54°C (130°F) using an air-to-cloth ratio of 3.0 to 1.0. Mechanical shakers (automatic) are used for cleaning. Dust from the baghouse is removed from the dust chambers under the baghouse by screw conveyors.

Emission measurements across the baghouse were conducted by EPA during January 17-27, 1978. Three arsenic and particulate measurements were made at the inlet and outlet locations of the converter building's fugitive baghouse. The arsenic test results are summarized in Tables C-25 and C-26, and the particulate test results are summarized in Tables C-27 and C-28. During the same period, three arsenic and particulate measurements were made at the inlet to the matte tapping baghouse and the calcine discharge duct. Due to the physical configuration of the matte tapping baghouse system, outlet tests could not be conducted. Measurements were conducted after the fan; however, a side stream of about $311 \text{ actual m}^3/\text{min}$ (11,000 acfm) of the matte tapping gases were split at the fan and ducted to the reverberatory furnace waste heat boilers for cooling purposes. This gas stream was measured only for volume flow. It was assumed that the pollutants in this gas stream

would have the same concentration as the gas stream measured going to the baghouse. Process conditions and control device parameters (when applicable) were carefully observed during all the periods when testing was conducted. Tests were conducted only when the process facilities and control equipment were operating within normal limits. Uncontrolled arsenic test results are summarized in Tables C-30 and C-32, and particulate tests are given in Tables C-31 and C-33.

C.3 ANACONDA

This smelter, when operating, was producing about 545 Mg (600 tons) of anode copper daily. Major process facilities consisted of a fluid-bed roaster, electric smelting furnace, six converters (three operational), and an anode furnace.

In this process, concentrates and precipitates are blended with silica flux in approximate proportions of 88, 2, and 10 percent, respectively. The blended materials (containing about 0.96 percent arsenic) are then fed to a Dorr-Oliver designed fluid-bed roaster by a screw feeder which controls the feed rate [typically about 91 Mg (100 tons) per hour] and maintains a seal on the roaster. Fluidizing air averages $1,062 \text{ Nm}^3/\text{min}$ (37,500 scfm). The air is supplied through tuyeres at the bottom of the roaster to keep the bed constantly fluidized at 1.3 m (70 in.) in depth.

The fluidized air reacts with the sulfur contained in the sulfide ores to form SO_2 and calcine. Approximately 45 percent of the sulfur contained in the feed material is eliminated. Because the reaction is exothermic, no auxiliary fuel is needed except at cold startup. The bed temperature is generally maintained at 582°C ($1,080^\circ\text{F}$). Most of the calcine which is produced (85 percent) exits the reactor as a fine dust suspended in the offgas stream. The offgases average $1,671 \text{ Nm}^3/\text{min}$ (59,000 scfm) at 543°C ($1,010^\circ\text{F}$). These gases are ducted through a series of primary and secondary cyclones where 90 to 95 percent of the suspended calcine is recovered. The underflow from the roaster accounts for the remaining 15 percent of the calcine produced.

An electric furnace is used for smelting. Drag conveyors continuously distribute calcine produced in the roaster in combination with some recycled flue dusts, along each side of the furnace through a series of charge pipes in the roof. The furnace working area is 18 m wide,

36 m long, and 30 m high. The bath area is 272 m^2 . The furnace is equipped with six carbon electrodes. Each is 1.65 m in diameter. The electrodes are energized by three transformers. Each has a capacity of 12 MVA. Normal voltage applied is between 150 and 180 volts. The furnace production capacity is 998 Mg (1,100 tons) of matte per day at 52 percent copper. Matte and slag are tapped as required from four matte and two slag tap holes to maintain normal depths (matte, 71 to 96 cm; slag, 102 to 152 cm). Offgases from the furnace average approximately $425 \text{ Nm}^3/\text{min}$ (15,000 scfm) at 645°C ($1,200^\circ\text{F}$).

Matte from the electric furnace is transported to one of three Pierce-Smith converters. Typical converter process feed rates include 41.5 Mg (45.7 tons) of matte, 4.5 Mg (5.0 tons) of flux, and 1.4 Mg (1.5 tons) of cold dope per hour. The offgas flow is about $2,832 \text{ Nm}^3/\text{min}$ (100,000 scfm) per blowing converter because of excessive air infiltration and typically contains about 2.5 percent SO_2 . Blister copper which is produced is transported to an anode furnace for further refining and subsequently poured into anodes on a casting wheel.

Process offgases from the electric furnace and converter blowing operations are combined. Approximately $2,070 \text{ Nm}^3/\text{min}$ (73,000 scfm) of the resultant gas stream is treated in a cooling chamber (humidified and cooled) and a venturi scrubber for particulate removal prior to entering a 600 Mg (design) double-contact acid plant. The remaining gases are combined with the fluid-bed roaster offgases and transported through a large balloon flue to a spray chamber/baghouse filtration plant for particulate control.

The combined gas stream, consisting of roaster, electric furnace, and converter process gases totaling about $5,664 \text{ Nm}^3/\text{min}$ (200,000 scfm) and ranging from 230 to 340°C (450 to 650°F) in temperature, exits the balloon flue and enters two parallel spray chambers where the gases are cooled to less than 110°C (230°F) with watersprays. Each spray chamber is 7.3 m wide, 4.3 m high, and 30 m long and is equipped with 10 sonic spray nozzles. Water requirements range from 265 to 303 liters/min (70 to 80 gpm). The cooled gas stream then passes through two of three fans (one is standby), each with a capacity of 6,230 actual Nm^3/min (220,000 scfm), prior to entering the baghouse.

The baghouse consists of 18 compartments aligned in two rows of nine. Each compartment is 4.3 by 14.3 m in cross section and 11.3 m high above the thimble flow. The 18 chambers are constructed of reinforced concrete above the thimble flow and are completely insulated. Each of the 18 compartments contains 240 Orlon bags which are 3.5 m in diameter and 7.7 m in length. The cloth area per compartment is $1,656 \text{ m}^2$. The baghouse net cloth area totals about $29,802 \text{ m}^2$. The baghouse is designed to effectively treat $11,328 \text{ actual Nm}^3/\text{min}$ ($400,000 \text{ acfm}$) at an air-to-cloth ratio of 1.25 to 1.00. Mechanical shakers are used for cleaning. The clean baghouse exhaust is transported via a high velocity insulated fiberglass flue to the base of the main stack and subsequently discharged to the atmosphere.

Inlet and outlet emission measurements for both arsenic and particulates were conducted by EPA across the spray chamber/baghouse on April 20-26, 1977. Sampling was conducted upstream of the spray chamber and downstream of the baghouse. Two sampling locations were required to obtain the inlet values. During all tests, process conditions were closely monitored, and testing was conducted only when the process facilities were operating within normal operating limits.

The arsenic and particulate test results for the spray chamber/baghouse are summarized in Tables C-34 through C-41.

C.4 PHELPS DODGE-AJO

This is a "green" feed smelter with a production capacity of about 168 Mg (185 tons) of anode copper per day. Major process facilities consist of a single reverberatory furnace, three Pierce-Smith converters, and oxidizing furnace, and an anode furnace. Emission control apparatus includes electrostatic precipitators for the control of particulate emissions from smelting and converting operations and a single-contact acid plant.

The reverberatory furnace, which is designed for wet smelting, is 9 m (30 ft) wide and 30 m (100 ft) long. It is fired with natural gas or fuel oil, depending on the availability of gas. The furnace walls and roof are constructed of silica brick, and the roof is of a sprung-arch design. The furnace charge components consist of concentrates (90 percent),

precipitates, limestone, and recycled flue dusts. In addition, converter slag is returned and processed. A charge, usually 1.8 to 3.6 Mg (2 to 4 tons), enters the furnace through one of six charge ports, three on each side of the furnace. Each port is equipped with a high-speed belt slinger to charge wet concentrates at considerable velocity. Slag and matte are tapped as required to maintain a normal bath depth of approximately 120 cm (46 in.) in the furnace.

Offgases from the reverberatory furnace pass through two parallel waste heat boilers where the gases are cooled to about 315°C (600°F), and a significant quantity of steam is produced for power generation. The exiting gas streams then enter a common plenum chamber for mixing prior to treatment in a hot electrostatic precipitator which is designed to handle 4,250 actual m³/min (150,000 acfm) at 315°C (600°F). The precipitator is a Joy-Western design, which was installed in 1973. It consists of two parallel units with two stages each, and it has a total collection area of 3,860 m². Gas treatment averages 6 seconds at a gas velocity of 0.9 m (3 ft)/sec. The pressure drop across the precipitator is 1.3 cm (0.5 in.) of water maximum. The unit has a design efficiency of 96.8 percent measured at its operating temperature.

Offgases from the converters pass through waste heat boilers where gases are cooled to about 315°C (600°F), and steam is generated from the removed heat. Gases enter a balloon flue and then pass through an electrostatic precipitator (ESP). The ESP has two independent horizontal parallel units with three fields each, which are designed to handle 5,940 actual m³/min (210,000 acfm) at 340°C (650°F) and 95,100 pascals (13.8 psia). Total ESP collecting surface area is 2,770 m² (29,808 ft²). After the converter gases leave the ESP, they pass onto the scrubbing section of the acid plant where they are treated in a humidifying tower, a cooling tower, and a mist precipitator. The cleaned offgases are then processed in a single absorption 544 Mg/day (600 ton/day) acid plant for SO₂ removal. Either 93 or 98 percent sulfuric acid can be produced. The acid plant tail gas is ducted to the main smelter stack.

Simultaneous inlet and outlet arsenic emission measurements were conducted by EPA on July 13-14, 1976, on the reverberatory furnace

ESP. Operating values for primary and secondary voltage and current and spark rate were monitored during all tests to ensure normal operation. In addition, reverberatory furnace operations were monitored for normal operation. The test results are summarized in Tables C-42 and C-43.

Inlet Arsenic emission measurements at the converter ESP inlet were conducted by EPA on June 13-15, 1978. Outlet arsenic emission measurements at the inlet of the acid plant, and acid plant outlet tests, were conducted at the same time. Test results are given in Tables C-44, through C47.

Fugitive emissions at Phelps Dodge-Ajo escape the primary hooding on the converters during the blowing cycle. These emissions are captured by fixed, semicircular-shaped secondary hoods attached to each converter. The hoods are approximately 1 m (3 ft) high at the tallest point. Although the secondary hoods are in operation during the blowing cycle, they are dampered when the converters are in the roll-out mode. The secondary system is designed to handle $1,980 \text{ Nm}^3/\text{min}$ (70,000 scfm) of gases. The gases are ducted uncontrolled to the main stack.

Fugitive emissions from the two matte tapping locations are controlled to a high degree by a rectangular duct about 60 to 90 cm (2 to 3 ft) above each tap hole. The rectangular vent opening is about 60 cm (24 in.) wide by 30 cm (12 in.) high and controls the fumes from the matte tapping hole and about one- to two-thirds down the matte launder which is not covered. The gas volume for this system is about $850 \text{ Nm}^3/\text{min}$ (30,000 scfm) and provides considerable draft to the vent for several feet. The matte runs into a 2.4 to 3 m (8 to 10 ft) launder and drops into a ladle on the floor below. Fumes from the matte launder, are drawn into the system handling the ladle emissions. Most of the time, few emissions escape from the matte launder.

Fugitive emissions from the matte pouring into and from the ladle are captured in a cubicle where the ladle is located. The ladle is placed on a specially designed cradle on rail tracks. An electric motor and pulley arrangement moves the ladle car in and out of the

cubicle. During the matte tap, the ladle is placed in the cubicle, and the doors are closed. The cubicle has ventilation ducts leading from it through a fan, and the gases are discharged through the main stack. The ventilation rate from the two cubicles is $1,700 \text{ Nm}^3/\text{min}$ (60,000 scfm).

Fugitive emissions from the slag tapping location are captured by using a hood (similar to matte tapping) at the slag tapping hole. The slag pours into an open launder and drops through a hole in the floor into a slag ladle positioned below. A hood near the ladle captures fume from the ladle. Normally, few emissions emanate from the slag tapping operation. The ventilation rate for the slag tapping system is about $850 \text{ Nm}^3/\text{min}$ (30,000 scfm). The duct from the slag tapping system is combined with the matte tapping duct system, and the gases are discharged out of the main stack.

Uncontrolled emission measurements for arsenic, particulate matter, and SO_2 were conducted by EPA for the secondary converter hood and matte tapping systems on May 10-12, 1978. During all tests, process conditions were closely monitored, and testing was conducted only when the process facilities were operating within normal limits. The arsenic test results are summarized for both systems in Tables C-48, and C-50. The particulate/ SO_2 test results are summarized for both systems in Tables C-49 and C-51.

C.5 PHELPS DODGE-HIDALGO

This smelter produces about 398 Mg (438 tons) of anode copper daily. Major process facilities consist of a rotary dryer, flash furnace, electric slag furnace, three converters, and two anode furnaces.

Concentrates, fluxes, and dusts are blended in approximate proportions of 88, 10, and 2.0 percent, respectively. Blended materials (containing 0.005 to 0.06 percent arsenic) are then fed to a rotary dryer at about 88 Mg (97 tons) per hour. These materials are heated by gases passing through the steam superheater and process air preheaters. The volume of combined gas streams is about $708 \text{ Nm}^3/\text{min}$ (25,000 scfm). They enter the dryer at about 315°C (600°F) and leave the dryer at about 80 to 100°C (180 to 220°F). The dryer discharges into a lift tank containing blended material and the fine dust portion of the ESP

cleaning the dryer offgases. The lift tank material is charged to the dry charge bins feeding the flash furnace.

A flash furnace is used for smelting. The feed material is charged through holes in the roof on the reaction shaft side of the furnace. The furnace reaction shaft is about 8 m (27 ft) inside diameter by about 36 ft high. The settling chamber is about 23 m (76.5 ft) long, 10 m (33 ft) wide, and 6 m (20.5 ft) high. The uptake shaft is about 9 m (30 ft) long, 6.6 m (21.5 ft) wide, and 16.6 m (54.5 ft) high. These are all inside dimensions. Ambient air, preheated to 370 to 450°C (700 to 850°F), is fed to the furnace; the process offgas is about 2,430 Nm³/min (86,000 scfm) at 1,200°C (2,200°F) and 10 percent SO₂. The furnace operating temperature is normally 1,350°C (2,460°F). Furnace production is about 715 Mg/day (650 tons/day) of matte and 1,650 Mg/day (1,500 tons/day) of slag. The slag from the flash furnace is tapped directly to the electric furnace for further copper recovery.

Matte from the flash furnace is transported to one of three Pierce-Smith converters. One converter usually is on a slag blow, one on a copper blow, and one is prepared for the next matte charges or on standby. The converter feed rates are 24 Mg (27 tons) of matte from the flash furnace, 8 Mg (9 tons) of matte from the electric furnace, and 1.7 Mg (1.9 tons) of flux per hour. The converters produce nearly 18 to 19 Mg/hr (20 to 21 tons/hr) of blister copper and 4.5 to 5.4 Mg/hr (5.0 to 6.0 tons/hr) of converter slag which is sent to the electric furnace.

An electric furnace is used for further processing of the flash furnace slag and converter slag. The furnace uses about 94 kWh per ton of charged material. The feed rates are about 66 Mg (60 tons) of flash furnace slag, 4.5 to 5.4 Mg (5.0 to 6.0 tons) of converter slag, and can handle about 11 Mg (12 tons) of reverberatories per hour. The furnace produces about 7.2 to 8.1 Mg/hr (8.0 to 9.0 tons/hr) of matte and 50 Mg/hr (tons/hr) of slag. The matte is transferred to the converters by ladle, and the slag is transported to a slag dump.

Blister copper produced in the converter is transported by ladle to one of two anode furnaces where it is further reduced to anode

copper. The copper is then poured into anode molds on a casting wheel at 16 to 17 Mg/hr (18 to 19 tons/hr). The anode copper is loaded on railcars and sent to a copper refinery for further processing.

Fugitive emissions escaping the primary hooding on the converters are captured by secondary hoods designed by the company. The secondary hoods have sliding doors 8.8 m (29 ft) long, 5.8 m (19 ft) wide, and 5.5 m (18 ft) high and cover the converter to the operator floor level. The design gas volume handled by the converter fugitive system is about 2,830 Nm³/min (100,000 scfm), and the temperature of the gases varies from 150 to 260°C (300 to 500°F).

Emission measurements were conducted by EPA during July 25-26, 1978, in the fugitive converter duct. The location was downstream of all the converters. Three emission measurements were made for uncontrolled arsenic. During the tests, process conditions were closely monitored, and testing was conducted only when the process facilities were operating within normal limits. The test results are summarized in Table C-52.

C.6 PHELPS DODGE-DOUGLAS

The Douglas Reduction Works is a calcine fed smelter producing about 322 Mg (365 tons) per day of 99.6 percent copper anodes. Copper anodes are sent to a copper refinery for further processing. The major units at the smelter include 24 roasters, 3 reverberatory furnaces, 5 converters, and 2 anode furnaces.

The roaster process consists of 24, 7-hearth Herreshoff roasters arranged in two parallel rows of 12. Only 18 are normally in operation at a time. The roasters are standard Herreshoff with a shell diameter of about 6.7 m (22 ft). Natural gas is introduced near the bottom of the roasters. As the hot gases rise, feed material introduced at the top is forced down through the roasters by the use of rabble arms which spread the feed around each hearth level and through openings at each level. About 154 to 163 Mg (170 to 180 tons) of calcine per roaster is produced each day.

Calcine from the roasters is discharged into holding hoppers where it is transferred by gravity to larry cars and delivered by rail to the reverberatory furnace.

The roaster calcine discharge emission control system consists of hoods covering the larry car with flexible screening or flaps hanging from the edges of the hoods to the top of the larry car. The hoods are split open 20 cm (8 in.) in the center to allow the power pole for the electric motor driving the larry cars to make contact with the electrical source. Unfortunately, when the hoppers are discharged into the larry car, the split allows calcine dust to escape from the hood into the building. The discharge ducts from the hoods are combined into a single duct leading to cyclones, a baghouse, a fan, and then discharged through a long duct leading to the roaster/reverberatory stack discharging to the atmosphere. Each hood can be dampered so that all the gas volume (draft) is available to the hoods used for calcine discharge.

The baghouse consists of eight compartments with 180 polyester bags per compartment. The bags are 328 cm (129 in.) long and 13 cm (5.0 in.) wide. The baghouse was designed to treat 1,130 actual m³/min (40,000 acfm) at ambient temperatures. Mechanical shakers are used for cleaning, and the baghouse and cyclone dusts are returned to the calcine hoppers by screw conveyors.

Inlet and outlet emission measurements for arsenic and particulates were conducted by EPA across the baghouse on May 3-5, 1978. Sampling was conducted upstream of the cyclones and downstream of the fan. During all tests, process conditions were closely monitored, and testing was conducted only when the process facilities were operating within normal operating limits.

Arsenic test results are summarized in Tables C-53 and C-54. Particulate test results are summarized in Tables C-55 and C-56.

C.7 KENNECOTT-MAGNA, UTAH

This smelter was designed to produce nearly 680 Mg (750 tons) of anode copper daily. Major process facilities consist of two rotary concentrate dryers, three continuous Noranda smelting vessels, four converters, and four anode furnaces.

Concentrates and precipitates, dusts, and slag concentrates are blended with silica flux in approximate proportions of 78, 4, 12, and 6 percent, respectively. Feed material from storage bins are fed to

conveyor belts that transport the material to a slinger (high-speed conveyor system) which charges the material into the smelting vessels. Matte and slag are normally tapped about every 30 minutes. The slag is taken to a processing station where it is cooled, crushed, and reprocessed to recover additional copper values (slag concentrate) which are returned to the smelting cycle. Matte is transported by ladle to the converters. Blister copper from the converters is transported by ladle to the anode furnaces. The strong SO_2 offgas streams from the smelting vessels and converters are cleaned and delivered to the acid plants.

Emissions from the matte tapping operation (hole) are captured in an enclosed cubicle. The ladle on a cradle car on rails (designed for this purpose), is in another cubicle beneath the matte tap floor level under the smelting vessel. Ducts direct the fumes from these operations into one duct which leads to the main fugitive duct system at the roof of the smelting and converter building. The main fugitive duct handles all fugitive emissions for the smelter area and discharges these fugitive emissions through a spray chamber and out the main stack (1,200 ft). The gas flow for the matte tapping hole system is $708 \text{ Nm}^3/\text{min}$ (25,000 scfm) and for the ladle system is $2,120 \text{ Nm}^3/\text{min}$ (75,000 scfm).

Emissions from the slag tapping operation are captured by a rectangular duct opening beside the tapping hole with a flow of $340 \text{ Nm}^3/\text{min}$ (12,000 scfm). A similar rectangular duct opening captures the emissions from the slag ladle in the area beneath the end of the smelting vessel. The flow rate for the collection of these emissions is $990 \text{ Nm}^3/\text{min}$ (35,000 scfm).

Emissions escaping the primary converter hoods during the blow, and some emissions escaping the converters during the roll-out mode, are captured by secondary hoods and ducted to the main fugitive duct, which was explained previously. The secondary hooding system has a steel shell constructed over the primary hoods. The primary hoods are permanent, nonmovable hood arrangements above the converters. This allows a transition to the fugitive duct system. The lower part of the secondary hood system consists of four doors that close over the converter and ladle area beneath the converter. One door turns down

from the top, two doors close in the center, and the last door moves across the bottom area, which completely covers the converter. Unlike other smelters with secondary hoods, the fugitive system at this smelter operates at all times, whether the converter is in the blowing cycle or roll-out mode. The secondary converter doors were not operable during the tests due to mechanical problems with the doors. The design gas volume per converter is 2,745 actual m^3/min (97,000 acfm) at 82°C (180°F).

The converter process gas stream was also source tested for uncontrolled arsenic. The tests were conducted before one of three fans and the control device to the acid plants. There is a settling chamber at the converters, and also a plenum chamber with dampers where the gases from each of the converters can be directed to one, two, or all three fans (as needed) to the acid plants. The gas volume for this process stream per converter is about 425 Nm^3/min (15,000 scfm).

Two rotary dryers are used at this smelter to dry concentrate feed for the smelting vessels. Emissions from the dryers are controlled by a cyclone followed by a spray chamber scrubber.

Uncontrolled arsenic emission measurements were conducted by EPA on November 1-14, 1978, on the slag and matte tapping system, converter secondary hood system, and the converter process gas stream before the control system. The rotary dryer scrubber outlet was also measured for arsenic during this period. During all tests, process conditions were closely monitored, and testing was conducted only when the process facilities were operating within normal limits.

The arsenic test results for these processes are summarized in Tables C-57 through C-62.

C.8 KENNECOTT-HAYDEN

The Kennecott Copper Corporation, Ray Mines Division, smelter at Hayden, Arizona, was originally put on stream in mid-1958 and extensively modernized in 1969 and 1973. The smelter produces nearly 227 Mg (250 tons) of anode copper daily and consists of a concentrator plant, fluid-bed roaster, reverberatory smelting furnace, three converters, two anode furnaces, an anode casting wheel, and a double-contact acid plant.

Concentrate and precipitates from the concentrator plant are blended with silica flux in proportions of 86.3, 2.2, and 11.5 percent, respectively. The blended materials (containing 6 to 12 percent moisture and less than 0.015 percent arsenic) are then fed to a Dorr-Oliver designed fluid-bed roaster by a screw feeder. The feeder controls the feed rate and maintains a seal on the roaster. The roaster feed rate typically ranges from 45.4 to 63.5 Mg/hr (50 to 70 tons/hr). Fluidizing air averages 425 Nm³/min (15,000 scfm). The air is supplied through 373 tuyeres at the bottom of the reactor vessel to keep the bed (approximately 1.8 m in depth) constantly fluidized.

The fluidizing air reacts with the sulfur contained in the sulfide ores to form SO₂ and calcine. Approximately 50 percent of the sulfur contained in the feed material is oxidized to SO₂. Because the reaction is exothermic, no auxiliary fuel is needed except for cold startup. The bed temperature is generally maintained between 565 and 620°C (1,050 to 1,150°F). Most of the calcine produced (85 percent) exits the reactor as a fine dust suspended in the offgas stream. The offgases average 623 Nm³/min (22,000 scfm). They are then ducted through a series of four primary and four secondary cyclones. In the cyclones, about 95 percent of the suspended calcine is recovered and subsequently conveyed by screw conveyor to the calcine storage bin. The underflow from the reactor, which accounts for about 15 percent of the calcine produced, is reclaimed through an underflow valve and transported to the calcine storage bin by a drag chain conveyor.

Calcine, precipitator dust, and flux are then fed to a single reverberatory furnace for smelting. The reverberatory furnace (a suspended arch design) is 9.1 m (30 ft) wide by 30.5 m (100 ft) long. The furnace is charged through two openings at the top by a pair of Wagstaff feeders. The furnace is charged every 15 minutes for a duration of 2 to 3 minutes. Unless actually being charged, a slight negative draft is maintained across the furnace (about -1.5 mm of H₂O). The furnace is fired with natural gas but is equipped with oil burners in the event gas service is interrupted. Slag from the furnace is periodically tapped into slag pots which are subsequently hauled by rail to the slag dump. About 650 tons are removed daily. Matte is tapped into ladles which are moved into the converter aisle when full.

The matte ladles are then picked up by an overhead crane and charged to one of three Pierce-Smith converters. Each is 4.0 m (13 ft) in diameter by 9.1 m (30 ft) long and equipped with 42 tuyeres. Present converter operation consists of keeping two converters on charge concurrently. Each is in the blowing cycle for 50 percent of the time for 24 hours. Air flowing at $595 \text{ Nm}^3/\text{min}$ (21,000 scfm) blows through the tuyeres in the matte charge, flux added, and iron oxide slag produced. The slag is then skimmed and poured into ladles. Unlike most domestic smelters, the converter slag is not charged to the reverberatory furnace, but is carried to a special slag pit where it is cooled and subsequently returned to the concentrator and blended with raw ore.

Additional matte and dope materials (reverts or copper scrap) are added to an active converter to produce approximately 90.7 Mg (100 tons) of blister copper per load. Converter process feed rates consist of about 650 Mg (718 tons) matte/day, 45.4 Mg (50 tons) dope/day, and 72.6 Mg (80 tons) flux/day. The finished blister copper is then poured into ladles and transported by overhead crane to one of two anode furnaces. The blister copper is completely oxidized with air and then reduced with propane or natural gas. Finished anode copper is then poured into anode molds on a single casting wheel. The anodes are cooled and subsequently loaded onto rail cars for shipment to a refinery. Anode production is about 226 Mg/day (250 tons/day) of 97.94 percent copper.

As noted previously, the calcine-laden roaster offgases pass through four parallel sets of primary and secondary cyclones. An estimated 95 percent of the dust (calcine) is recovered, and the gas stream is cooled from 565°C ($1,050^\circ\text{F}$) to about 316°C (600°F). The cyclone exhaust, which has a dust loading of about 57.2 g/Nm^3 (25 gr/scf), then enters a venturi-type scrubber where most of the particulate is collected. The scrubbing liquid consists of weak acid which is injected into the venturi throat at a rate of 1,500 liters/min (395 gpm). The resultant pressure drop across the throat is about 406 mm (16 in.) of water. The gas stream then enters the smaller of two Peabody scrubbing towers. The larger tower is used for scrubbing and cooling the converter

offgas stream. Both towers consist of a lower humidifying section and an upper cooling section. The discharge from the venturi enters the humidifying section and passes upward through a weak acid spray from spray nozzles located at the top of the section. The coarser solids are removed and the heat of the gas evaporates the weak acid water, effectively cooling the gas stream to about 68°C (155°F). The saturated gas stream then enters the cooling section where it passes through three perforated plates (four on the converter tower) for flow distribution and acid bubble formation. The weak acid flowing across the plates cools the gas stream to about 46°C (115°F). The pressure drop across both the venturi and Peabody scrubbers (which services the roaster offgases) is about 610 mm (24 in.) of water. The clean roaster gas stream (which contains about 12 percent SO₂) is then combined with the cleaned converter gas stream prior to entering the acid plant.

The reverberatory furnace offgases average approximately 3,682 Nm³/min (130,000 scfm). They then pass through a pair of waste heat boilers at approximately 1,260°C (2,300°F) and exit at 343°C (650°F). The recovered heat is used to produce steam. The gases are then transported through a balloon flue to an ESP for particulate control. The ESP is a Koppers design and consists of four parallel chambers. The chambers have three fields in a series and a total collection area of 5,016 m² (54,000 ft²). The gas retention time within the ESP is about 14 seconds. The average gas velocity is 0.5 m (1.6 ft) per second. The gases exit the precipitator at about 288°C (550°F) and are subsequently discharged through the main stack.

The offgases generated by converter blowing total 1,982 Nm³/min (70,000 scfm). They are collected in water-cooled hoods and then exhausted through a gas cooler in which the gas stream is treated by a concurrently flowing, ultrasonically dispersed water spray. The cooled gas stream (371°C) flows through an induced fan plenum and into an electrostatic precipitator for particulate removal. The precipitator, manufactured by Western Precipitator, has two chambers with three fields per chamber. The total collection area of the chamber is 3,716 m² (40,000 ft²). Gas retention time is about 9 sec. The average gas velocity is about 1.2 m/sec (4 ft/sec). Following the ESP, the gas stream (which contains about 5 percent SO₂) enters the larger of

the two Peabody scrubbing towers and is treated similarly to the roaster gas stream.

After the cleaned and cooled roaster and converter gases are combined, the resultant gas stream enters three parallel trains of two mist precipitators in series, where acid mist and any remaining solids are precipitated. The gas stream (which typically contains 5 to 8 percent SO_2) then enters the double absorption acid plant where it is dried, the SO_2 converted to SO_3 , and the SO_3 absorbed in acid to form strong acid. Although designed to produce 1,769 Mg (1,950 tons) of sulfuric acid per day, only about 771 Mg (850 tons) per day of 93.5 percent strength sulfuric acid is actually produced. This represents about 99.5 percent conversion.

The gas stream exiting the mist precipitator enters a drying tower where 93 percent acid is used to remove water vapor prior to entering the converter and absorbing systems. The gas stream then goes to the main blowers. One, two, or three 1,490 kW (2,000 hp) blowers are used depending on the volume of gas available for processing. The gas stream exits the main blowers into the converter system; the SO_2 contained in the gas stream is then converted to SO_3 . The converter contains four layers of vanadium catalyst arranged in three passes. The first pass consists of two layers; the second and third passes each have one layer. Tube and shell heat exchangers are used to preheat the SO_2 gas stream to the operating temperature by utilizing the heat generated from the exothermic chemical reaction within the converter. The preheated gas enters the top of the converter and passes through the catalyst layers, exiting the converter after each pass, and entering a heat exchanger for cooling. During plant startups or during periods of low SO_2 gas strength, a preheater is used to raise or maintain the catalyst temperature at a level at which conversion will take place.

Two absorbing towers are used, an interpass absorber and a final absorber. The gas leaving the second converter pass goes through two heat exchangers and then to the interpass absorber where the SO_3 is absorbed by 98 to 99 percent acid. The gas stream then enters the final converter pass where nearly all the remaining SO_2 is converted.

The gas stream then enters the final absorber where the last traces of SO_3 are absorbed. The acid product is pumped through a series of cooling coils and then stored in any of four 5,000-ton storage tanks. The exit gas from the final absorber passes through a mist eliminator and is then exhausted through a 30.5 m (100 ft) stack. The SO_2 concentration in the exhaust gas is generally about 230 ppm.

Arsenic emission measurements were conducted by EPA on December 10-13, 1976. Concurrent inlet and outlet measurements were performed across the venturi and Peabody scrubbers. The scrubbers treat the roaster offgases for particulates before they are combined with converter process gases and subsequently treated for SO_2 in the double-contact acid plant. Additional arsenic measurements were made at the acid plant outlet.

Process conditions were carefully observed, and testing was conducted only when the subject process facilities were operating within normal operating limits. The test results are summarized in Tables C-63, C-64, and C-65.

C.9 TAMANO SMELTER (HIBI KYODO SMELTING CO.,) JAPAN

The Tamano smelter, a toll smelting facility, is located 7 km (11 miles) southwest of Uno port and has a production capacity of 8,500 tons per month of electrolytic copper. The smelter consists of one flash furnace, three converters, two refining furnaces, and one concentrate dryer. Of the three converters, usually one is in operation, one is kept hot, and one is kept on standby.

Converter primary offgases which range between 65,000 and 75,000 Nm^3/h (38,000 to 44,000 scfm) and flash furnace offgases which range between 65,000 and 80,000 Nm^3/h (38,000 to 47,000 scfm) are treated in two separate pairs of electrostatic precipitators for particulate removal, then introduced into a 156,000 Nm^3/h (92,000 scfm) capacity acid plant for SO_2 removal. SO_2 content of the converter and flash furnace gases usually range between 6.5 and 7.5 percent. The acid plant SO_2 removal efficiency is 99.7 percent. Outlet gases which contain 140 ppm SO_2 are vented through the main stack. A 98 percent sulfuric acid is produced at a rate of 30,000 tons/month at full capacity.

Offgases from refining furnaces are combined with gas from the power plant and passed through the concentrate dryer. Total gases from the dryer are treated in a pair of electrostatic precipitators prior to introduction to a desulfurization plant.

Each converter system is equipped with a secondary hood system for fugitive gas capture which encloses the converter mouth and ladle used for handling molten materials. The hood has two automatic front doors which are operated pneumatically. The hood has a movable roof which is slightly inclined toward the front. During closing, the roof slides to its right. During the converter operation when the hood roof is opened, fugitive emissions from the roof are controlled by an air curtain system [rated at 70,000 Nm³/hr (41,000 scfm)].

The bulk of fugitive gases up to 190,000 Nm³/hr (112,000 scfm) with low SO₂ content collected in the secondary hood are passed through a dust chamber, a baghouse system, and the main stack to the atmosphere.

Another smaller volume, fugitive gas stream with a high SO₂ content is continuously fed to a 200,000 Nm³/hr (118,000 scfm) capacity desulfurization plant. Gas volume to the desulfurization plant includes about 72,000 Nm³/hr (42,000 acfm) from the refining furnace, power plant, and flash dryer, and about 30,000 Nm³/hr (18,000 scfm) leakage gases from the converters and refining furnaces.

On March 12 and 13, 1980, visible emission observations were made of the converter secondary hood system during various modes of converter operation. Tables C-75 through C-80 present the results of these observations.

C.10 TEST DATA (TABLES)

This section contains summary data tables of the arsenic and particulate emission tests, and the visible emissions observations, conducted by EPA between December 1976, and June 1980. The following notes apply to Tables C-3 through C-65:

- a) Data not reported.
- b) Run no. 1 of Reverberatory-North data was performed on 6/28/77.
- c) Not applicable.

Table C-1. SUMMARY OF EMISSION TESTS

Plant	Process Facility	Control Equipment	Sampling Location(s)	Sample Type
Phelps Dodge Ajo, Arizona	Acid plant from converters	Hot ESP + mist ESP + coolers	Inlet and outlet	Arsenic
	Reverberatory furnace (matte and slag tapping)	None	Before entering main stack	Arsenic Particulate SO ₂
	Converters (blow cycle)	None	Before entering main stack	Arsenic Particulate SO ₂
	Multihearth roasters and reverberatory furnace	Spray chamber/ cold ESP	Inlet and outlet	Arsenic Particulate
ASARCO El Paso, Texas	Multihearth roaster discharge	Discharged into above system	Inlet	Arsenic Particulate SO ₂
	Reverberatory furnace (matte tapping)	Baghouse	Inlet	Arsenic Particulate SO ₂
	Converter building	Baghouse	Inlet and outlet	Arsenic Particulate SO ₂
	Converter secondary hoods	None	Inlet	Arsenic
Phelps Dodge Playas, New Mexico	Multihearth roaster discharge	Baghouse	Inlet and outlet	Arsenic Particulate SO ₂
Phelps Dodge Douglas, Arizona				

Table C-1. SUMMARY OF EMISSION TESTS (Concluded)

Plant	Process Facility	Control Equipment	Sampling Location(s)	Sample Type
ASARCO Tacoma, Washington	Arsenic roasters	Baghouse	Inlet and outlet	Arsenic SO ₂
	Reverberatory furnace	Cold ESP	Outlet	Arsenic
	Matte tapping	Cold ESP	Inlet	Arsenic
	Slag tapping	Cold ESP	Inlet	Arsenic
	Converter slag return	Cold ESP	Inlet	Arsenic
Kennecott Magna, Utah	Slag dumping	None	Dump site (grab samples of slag)	Arsenic
	Metallic arsenic	Baghouse	Inlet and outlet	Arsenic
	Anode furnace	None	Inlet	Arsenic (tests by ASARCO)
	Converters	Acid Plant	Inlet	Arsenic
	Converter	None	Uncontrolled duct	Arsenic SO ₂
	Secondary hood	None	Uncontrolled duct	Arsenic SO ₂
	Roll-out cycle	None	Uncontrolled duct	Arsenic SO ₂
	Moranda furnace	None	Uncontrolled duct	Arsenic SO ₂
	Matte tapping	None	Uncontrolled duct	Arsenic SO ₂
	Slag tapping	None	Uncontrolled duct	Arsenic SO ₂
Anaconda Anaconda, Montana Kennecott Hayden, Arizona	Concentrate dryer	Scrubber	Outlet	Arsenic
	Fluid-bed roaster, electric furnace, and converter	Spray chamber/baghouse	Inlet and outlet	Arsenic Particulate
	Fluid-bed roaster	Venturi scrubber	Inlet and outlet	Arsenic
	Fluid-bed roaster and converters	Acid plant	Outlet	Arsenic

Table C-2. INDEX TO ARSENIC AND PARTICULATE TEST DATA TABLES BY PROCESS FACILITY AND SAMPLE TYPE

Process Facility	Plant	Control Equipment	Sample Type	Table Numbers in Appendix C
Arsenic roasters	ASARCO-Tacoma	Baghouse	Arsenic	C-3, C-4
Fluid-bed roaster	Kennecott-Hayden	Venturi scrubber	Arsenic	C-63, C-64
Multi-hearth roasters and reverberatory furnace	ASARCO-El Paso	Spray chamber/ cold ESP	Arsenic Particulate	C-13, C-14, C-15, C-16, C-17 C-18, C-19, C-20, C-21, C-22, C-29
Fluid-bed roaster, electric furnace, and converter	Anaconda-Anaconda	Spray chamber/ baghouse	Arsenic Particulate	C-34, C-35, C-36, C-37 C-38, C-39, C-40, C-41
Fluid-bed roaster and converters	Kennecott-Hayden	Acid plant	Arsenic	C-65
Calcine discharge	ASARCO-Tacoma	None	Arsenic	C-9
Roaster calcining fugitives	ASARCO-El Paso	Spray chamber/ cold ESP	Arsenic Particulate	C-30 C-31
Multi-hearth roaster fugitive discharge	Phelps Dodge- Douglas	Baghouse	Arsenic Particulate	C-53, C-54 C-55, C-56
Reverberatory furnace	ASARCO-Tacoma	Cold ESP	Arsenic	C-8
Reverberatory furnace Matte tapping	ASARCO-Tacoma	Cold ESP	Arsenic	C-10
Matte tapping	ASARCO-El Paso	Baghouse	Arsenic Particulate	C-32 C-33
Matte and slag tapping	Phelps Dodge-Ajo	None	Arsenic Particulate	C-48 C-49
Noranda furnace Matte tapping	Kennecott-Magna	None	Arsenic	C-59
Reverberatory furnace Slag tapping	ASARCO-Tacoma	Cold ESP	Arsenic	C-11
Noranda furnace Slag tapping	Kennecott-Magna	None	Arsenic	C-60
Reverberatory furnace Converter slag return	ASARCO-Tacoma	Cold ESP	Arsenic	C-12

Table C-2. INDEX TO ARSENIC AND PARTICULATE TEST DATA TABLES BY PROCESS FACILITY AND SAMPLE TYPE (Concluded)

Process Facility	Plant	Control Equipment	Sample Type	Table Numbers in Appendix C
Converters	ASARCO-El Paso	Acid plant	Arsenic	C-23, C-24
Converters (blow cycle)	Phelps Dodge-Ajo	None	Arsenic Particulate	C-50 C-51
Converters	Kennecott-Magna	Acid plant	Arsenic	C-58
Converter fugitives Full cycle	Kennecott-Magna	None	Arsenic	C-61
Rollout phase	Kennecott-Magna	None	Arsenic	C-62
Acid plant from converters	Phelps Dodge-Ajo	Hot ESP, mist ESP and coolers	Arsenic	C-42, C-43, C-44, C-45, C-46, C-47
Converter building	ASARCO-El Paso	Baghouse	Arsenic Particulate	C-25, C-26 C-27, C-28
Converter secondary hoods	Phelps Dodge-Hidalgo	None	Arsenic	C-52
Metallic arsenic process	ASARCO-Tacoma	Baghouse	Arsenic	C-5, C-6, C-7
Concentrate dryers	Kennecott-Magna	Scrubber	Arsenic	C-57

Table C-3. SUMMARY OF ARSENIC TEST DATA -- ROASTER
BAGHOUSE INLET, ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/15/78	9/15/78	9/16/78	
Test Duration - min.	80	84	80	81
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	173,621	175,277	184,141	177,680
Temperature (°F)	201	185	203	197
Stream (vol. %):				
Water	4.4	3.4	4.5	4.1
CO ₂	0.2	0.2	0.2	0.2
O ₂	20.4	20.4	20.4	20.4
SO ₂	0.65	0.96	0.81	0.81
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.1371	0.1280	0.1101	0.1248
gr/acf	0.1301	0.1249	0.1092	0.1212
lb/hr	204.0	192.2	173.6	189.6
Total catch				
gr/dscf	0.1377	0.1295	0.1111	0.1258
gr/acf	0.1303	0.1261	0.1103	0.1220
lb/hr	204.3	194.1	175.2	190.9
Percent Isokinetic	94.6	108.2	95.0	

Table C-4. SUMMARY OF ARSENIC TEST DATA -- ROASTER
BAGHOUSE OUTLET, ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/15/78	9/15/78	9/16/78	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	171,887	174,633	178,671	175,064
Temperature (°F)	191	189	180	187
Stream (vol. %):				
Water	5.9	5.0	5.6	5.5
CO ₂	0.2	0.2	0.2	0.2
O ₂	20.4	20.4	20.4	20.4
SO ₂	0.70	0.80	0.52	0.67
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00027	0.00027	0.00028	0.00027
gr/acf	0.00026	0.00026	0.00028	0.00026
lb/hr	0.396	0.401	0.439	0.412
Total catch				
gr/dscf	0.00028	0.00028	0.00065	0.00040
gr/acf	0.00027	0.00027	0.00064	0.00039
lb/hr	0.416	0.428	0.993	0.612
Percent Isokinetic	99.5	100.1	102.3	

Table C-5. SUMMARY OF ARSENIC TEST DATA --
 ARSENIC KITCHEN BAGHOUSE INLET, ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/24/78	9/24/78	9/25/78	
Test Duration - min.	96	96	96	96
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	14,505	16,590	17,560	16,218
Temperature (°F)	133	136	140	136
Stream (vol. %):				
Water	3.6	4.0	2.9	3.5
CO ₂	0.2	0.2	0.2	0.2
O ₂	20.8	20.8	20.8	20.8
SO ₂	0.32	0.57	0.49	0.46
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.7503	0.6632	0.6593	0.6909
gr/acf	0.7484	0.6400	0.6400	0.6755
lb/hr	93.23	94.21	99.18	95.54
Total catch				
gr/dscf	0.7504	0.6632	0.6695	0.6944
gr/acf	0.7486	0.6454	0.6402	0.6756
lb/hr	93.23	94.21	99.18	95.54
Percent Isokinetic	99.2	97.5	94.8	

Table C-6. SUMMARY OF ARSENIC TEST DATA --
METALLIC ARSENIC BAGHOUSE INLET, ASARCO-TACOMA SMELTER

Run No.	1	2*	3	Average
Date	9/24/78	9/24/78	9/25/78	
Test Duration - min.	94	96	96	95
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	12,989	15,147	15,469	14,533
Temperature (°F)	242	233	207	227
Stream (vol. %):				
Water	2.0	3.1	2.7	2.6
CO ₂	0.1	0.1	0.1	0.1
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.24	0.17	0.22	0.21
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.8440	0.0004	0.9289	0.5910
gr/acf	0.8343	0.0004	0.8914	0.5273
lb/hr	93.79	0.0544	123.0	72.27
Total catch				
gr/dscf	0.8441	0.0006	0.9289	0.5912
gr/acf	0.8345	0.0006	0.8915	0.5275
lb/hr	93.81	0.0813	123.0	72.29
Percent Isokinetic	100.7	94.5	98.5	

* During this sample run the metallic arsenic process may not have been operating.

Table C-7. SUMMARY OF ARSENIC TEST DATA --
 ARSENIC BAGHOUSE OUTLET (METALLIC AND KITCHEN),
 ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/24/78	9/24/78	9/25/78	
Test Duration - min.	96	96	96	96
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	29,109	35,958	33,726	32,931
Temperature (°F)	182	163	160	168
Stream (vol. %):				
Water	1.0	2.1	2.8	2.0
CO ₂	0.2	0.2	0.2	0.2
O ₂	20.4	20.4	20.4	20.4
SO ₂	0.28	0.19	0.63	0.37
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0303	0.0068	0.0417	0.0253
gr/acf	0.0303	0.0066	0.0401	0.0248
lb/hr	7.59	2.11	12.07	7.26
Total catch				
gr/dscf	0.0304	0.0069	0.0420	0.0255
gr/acf	0.0304	0.0067	0.0403	0.0249
lb/hr	7.61	2.13	12.14	7.29
Percent Isokinetic	97.5	101.3	97.8	

Table C-8. SUMMARY OF ARSENIC TEST DATA --
REVERB ESP OUTLET, ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/15/78	9/16/78	9/18/78	
Test Duration - min.	116	108	108	111
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	441,557	454,539	443,619	443,238
Temperature (°F)	220	214	188	207
Stream (vol. %):				
Water	4.4	5.1	3.7	4.4
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.54	1.17	0.32	0.68
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.01632	0.00897	0.00375	0.00968
gr/acf	0.01538	0.00863	0.00364	0.00921
lb/hr	61.68	35.04	13.99	36.90
Total catch				
gr/dscf	0.01669	0.00915	0.00418	0.01000
gr/acf	0.01574	0.00881	0.00405	0.00953
lb/hr	63.09	25.77	15.59	38.15
Percent Isokinetic	104.2	107.7	102.2	

Table C-9. SUMMARY OF ARSENIC TEST DATA --
CALCINE DISCHARGE, ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/20/78	9/20/78	9/21/78	
Test Duration - min.	15	13	7	12
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	1,239	1,293	1,524	1,352
Temperature (°F)	78	78	80	79
Stream (vol. %):				
Water	2.5	0.0	0.0	0.83
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.07	1.32	0.22	0.54
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0939	0.1463	0.2074	0.1399
gr/acf	0.0936	0.1458	0.2053	0.1384
lb/hr	1.007	1.623	2.721	1.784
Total catch				
gr/dscf	0.0946	0.1497	0.0292	0.1418
gr/acf	0.0943	0.1492	0.2071	0.1724
lb/hr	1.014	1.661	2.744	1.806
Percent Isokinetic	96.6	94.2	108.1	

Table C-10. SUMMARY OF ARSENIC TEST DATA --
MATTE TAPPING, ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/19/78	9/20/78	9/21/78	
Test Duration - min.	78	75	74	76
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	18,944	18,181	18,329	18,485
Temperature (°F)	134	163	164	154
Stream (vol. %):				
Water	1.5	0.8	0.9	1.1
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.18	0.39	0.21	0.26
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.02146	0.10649	0.10332	0.07533
gr/acf	0.02127	0.10394	0.10130	0.07427
lb/hr	3.490	16.59	16.24	12.11
Total catch				
gr/dscf	0.02297	0.10657	0.10344	0.07591
gr/acf	0.02271	0.10403	0.10142	0.07484
lb/hr	3.26	16.60	16.26	12.20
Percent Isokinetic	90.5	91.0	90.0	

Table C-11. SUMMARY OF ARSENIC TEST DATA --
SLAG TAPPING, ASARCO-TACOMA SMELTER

Run No.	1	2	3	Average
Date	9/19/78	9/20/78	9/20/78	
Test Duration - min.	120	111	60	97
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	18,351	16,571	17,219	17,380
Temperature (°F)	68	106	119	98
Stream (vol. %):				
Water	1.5	2.3	0.3	1.4
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.03	0.05	0.07	0.05
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00340	0.01009	0.00790	0.00676
gr/acf	0.00335	0.01005	0.00784	0.00670
lb/hr	0.536	1.431	1.170	1.046
Total catch				
gr/dscf	0.00348	0.01011	0.00793	0.00681
gr/acf	0.00343	0.01007	0.00787	0.00675
lb/hr	0.548	1.434	1.175	1.052
Percent Isokinetic	91.2	95.9	92.1	

Table C-12. SUMMARY OF ARSENIC TEST DATA --CONVERTER SLAG
RETURN, ASARCO-TACOMA SMELTER

Run No.	1
Date	9/19-21/78
Test Duration - min.	23
Charge Rate - ton/hr	a
Arsenic Rate - lb/hr	a
<u>Stack Effluent</u>	
Flow rate (dscfm)	23,207
Temperature (°F)	95
Stream (vol. %):	
Water	0.8
CO ₂	0.0
O ₂	20.0
SO ₂	0.7
<u>Emissions - Arsenic</u>	
Probe, cyclone, and filter catch	
gr/dscf	0.00139
gr/acf	0.00135
lb/hr	0.2763
Total catch	
gr/dscf	0.00149
gr/acf	0.00145
lb/hr	0.2962
Percent Isokinetic	91.4

Table C-13. SUMMARY OF ARSENIC TEST DATA --
R & R ESP INLET (ROASTER), ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	6/26/77	6/27/77	6/28/77	
Test Duration - min.	116	120	120	119
Charge Rate - ton/hr	41.2	28.9	42.7	37.6
Arsenic Rate - lb/hr	98.0	172.9	395.5	222.1
<u>Stack Effluent</u>				
Flow rate (dscfm)	140,927	149,764	56,040	115,577
Temperature (°F)	173	211	231	205
Stream (vol. %):				
Water	6.7	5.3	9.4	7.2
CO ₂	0.0	0.5	0.4	0.3
O ₂	16.6	18.7	20.5	18.6
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0060	0.0080	0.0312	0.0109
gr/acf	0.0040	0.0052	0.0188	0.0069
lb/hr	7.200	10.32	14.99	9.807
Total catch				
gr/dscf	0.0100	0.0103	0.0380	0.0147
gr/acf	0.0068	0.0067	0.0229	0.0094
lb/hr	12.12	13.21	18.25	13.58
Percent Isokinetic	102.4	66.8	109.2	

Table C-14. SUMMARY OF ARSENIC TEST DATA --
R & R ESP INLET (REVERB-NORTH), ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	6/26/77	6/27/77	6/28/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	41.2	28.9	42.7	37.6
Arsenic Rate - lb/hr	98.0	172.9	395.5	222.1
<u>Stack Effluent</u>				
Flow rate (dscfm)	38,664	42,288	40,421	40,458
Temperature (°F)	932	786	753	824
Stream (vol. %):				
Water	6.9	17.9	19.0	14.6
CO ₂	7.6	7.6	7.5	7.6
O ₂	9.9	9.9	9.9	9.9
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0471	0.2888	0.2903	0.2123
gr/acf	0.0145	0.0870	0.0890	0.0646
lb/hr	15.61	104.7	100.6	74.95
Total catch				
gr/dscf	0.1219	0.2951	0.3177	0.2475
gr/acf	0.0374	0.0889	0.0974	0.0753
lb/hr	40.39	107.0	110.1	86.81
Percent Isokinetic	103.8	107.1	112.7	

Table C-15. SUMMARY OF ARSENIC TEST DATA --
R & R ESP INLET (REVERB-SOUTH), ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	6/26/77	6/27/77	6/28/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	41.2	28.9	42.7	37.6
Arsenic Rate - lb/hr	98.0	172.9	395.5	222.1
<u>Stack Effluent</u>				
Flow rate (dscfm)	19,759	22,057	25,981	22,599
Temperature (°F)	787	766	614	722
Stream (vol. %):				
Water	14.2	13.4	25.2	16.6
CO ₂	8.1	8.1	8.2	8.1
O ₂	9.3	9.3	9.2	9.3
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.1280	0.7878	0.6096	0.5272
gr/acf	0.0404	0.2544	0.1949	0.1692
lb/hr	21.68	148.9	135.7	106.8
Total catch				
gr/dscf	0.1289	0.7967	0.6462	0.5444
gr/acf	0.0407	0.2572	0.2067	0.1747
lb/hr	21.83	150.6	143.9	110.5
Percent Isokinetic	95.8	97.7	113.4	

Table C-16. SUMMARY OF ARSENIC TEST DATA --
R & R ESP INLET (TOTAL), ASARCO-EL PASO SMELTER *

Run No.	1	2	3	Average
Date	6/26/77	6/27/77	6/28/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	41.2	28.9	42.7	37.6
Arsenic Rate - lb/hr	98.0	172.9	395.5	222.1
<u>Stack Effluent</u>				
Flow rate (dscfm)	199,350	214,109	122,442	178,634
Temperature (°F)	381	382	485	411
Stream (vol. %):				
Water	7.5	8.6	15.9	10.1
CO ₂	2.3	2.7	4.4	2.9
O ₂	14.6	3.3	14.6	15.5
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0261	0.1438	0.2426	0.1218
gr/acf	0.0096	0.0470	0.0812	0.0405
lb/hr	44.49	263.9	251.3	191.6
Total catch				
gr/dscf	0.0435	0.1476	0.2594	0.1344
gr/acf	0.0161	0.0487	0.0865	0.0452
lb/hr	74.34	270.8	272.3	210.9
Percent Isokinetic	c	c	c	

* These data are derived from Tables C-13, C-14, and C-15.

Table C-17. SUMMARY OF ARSENIC TEST DATA --
R & R ESP OUTLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	6/26/77	6/27/77	6/28/77	
Test Duration - min.	153	153	153	153
Charge Rate - ton/hr	41.2	28.9	42.7	37.6
Arsenic Rate - lb/hr	98.0	172.9	395.5	222.1
<u>Stack Effluent</u>				
Flow rate (dscfm)	201,030	209,891	222,719	211,213
Temperature (°F)	216	219	221	219
Stream (vol. %):				
Water	6.8	6.1	1.4	4.8
CO ₂	3.5	3.5	0.0	2.3
O ₂	19.0	19.0	20.8	19.6
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0009	0.0031	0.0014	0.0018
gr/acf	0.0006	0.0019	0.0010	0.0012
lb/hr	1.603	5.503	2.761	3.302
Total catch				
gr/dscf	0.0020	0.0041	0.0018	0.0026
gr/acf	0.0012	0.0026	0.0012	0.0017
lb/hr	3.401	7.400	3.393	4.723
Percent Isokinetic	100.4	100.4	95.4	

Table C-18. SUMMARY OF PARTICULATE TEST DATA -- R & R ESP
INLET (ROASTER), ASARCO-EL PASO SMELTER

Run No.	1	2	Average
Date	6/29/77	6/30/77	
Test Duration - min.	120	90	105
Charge Rate - ton/hr	43.5	47.6	45.5
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	68,948	63,256	66,102
Temperature (°F)	190	197	193
Stream (vol. %):			
Water	9.2	10.5	9.8
CO ₂	1.8	1.4	1.6
O ₂	20.7	17.9	19.3
SO ₂	a	a	a
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	2.245	1.954	2.106
gr/acf	1.439	1.222	1.335
lb/hr	1,327	1,059	1,199
Total catch			
gr/dscf	2.276	1.977	2.133
gr/acf	1.458	1.236	1.352
lb/hr	1,345	1,072	1,214
Percent Isokinetic	122.0	108.5	

Table C-19. SUMMARY OF PARTICULATE TEST DATA -- R & R ESP
INLET (REVERB-NORTH), ASARCO-EL PASO SMELTER

Run No.	1	2	Average
Date	6/28/77	6/30/77	
Test Duration - min.	120	120	120
Charge Rate - ton/hr	43.5	47.6	45.5
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	40,711	39,889	40,300
Temperature (°F)	687	672	680
Stream (vol. %):			
Water	18.8	16.1	17.5
CO ₂	5.5	8.0	6.7
O ₂	5.0	13.2	9.1
SO ₂	a	a	a
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	2.098	1.474	1.786
gr/acf	0.6814	0.5011	0.5913
lb/hr	732.0	504.0	619.2
Total catch			
gr/dscf	2.188	1.534	1.861
gr/acf	0.7106	0.5214	0.6170
lb/hr	763.3	524.4	643.9
Percent Isokinetic	109.8	111.6	

Table C-20. SUMMARY OF PARTICULATE TEST DATA -- R & R ESP
INLET (REVERB-SOUTH), ASARCO-EL PASO SMELTER

Run No.	1	2	Average
Date	6/29/77	6/30/77	
Test Duration - min.	120	120	120
Charge Rate - ton/hr	43.5	47.6	45.5
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	22,504	25,680	24,092
Temperature (°F)	751	728	739
Stream (vol. %):			
Water	9.6	12.8	11.3
CO ₂	9.9	8.6	9.2
O ₂	3.4	8.5	6.1
SO ₂	a	a	a
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	0.9863	5.3713	3.323
gr/acf	0.3377	1.8078	1.121
lb/hr	190.2	1,182	718.8
Total catch			
gr/dscf	1.0892	5.3974	3.385
gr/acf	0.3730	1.8166	1.142
lb/hr	210.1	1,188	731.3
Percent Isokinetic	109.7	112.3	

Table C-21. SUMMARY OF PARTICULATE TEST DATA -- B & R ESP
INLET (TOTAL), ASARCO-EL PASO SMELTER

Run No.	1	2	Average
Date	6/29/77 ^b	6/30/77	
Test Duration - min.	120	120	120
Charge Rate - ton/hr	43.5	47.6	45.5
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	132,163	128,825	130,494
Temperature (°F)	439	450	444
Stream (vol. %):			
Water	12.2	12.7	12.5
CO ₂	4.3	4.9	4.6
O ₂	12.9	14.6	13.7
SO ₂	a	a	a
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	1.9854	2.1270	2.2319
gr/acf	1.0180	1.1154	1.0658
lb/hr	2,249	2,745	2,494
Total catch			
gr/dscf	2.0468	2.5217	2.2801
gr/acf	1.0431	1.1306	1.0862
lb/hr	2,318	2,784	2,548
Percent Isokinetic	c	c	

* These data are derived from Tables C-18, C-19, and C-20.

Table C-22. SUMMARY OF PARTICULATE TEST DATA -- R & R ESP
OUTLET, ASARCO-EL PASO SMELTER

Run No.	1	2	Average
Date	6/28/77	6/30/77	
Test Duration - min.	153	153	153
Charge Rate - ton/hr	43.5	47.6	45.5
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	215,414	233,278	224,346
Temperature (°F)	220	220	220
Stream (vol. %):			
Water	10.7	8.7	9.7
CO ₂	1.3	2.0	1.7
O ₂	19.0	20.0	19.5
SO ₂	a	a	a
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	0.0489	0.0372	0.0427
gr/acf	0.0292	0.0228	0.0259
lb/hr	89.79	74.28	81.73
Total catch			
gr/dscf	0.0619	0.0478	0.0546
gr/acf	0.0372	0.0286	0.0327
lb/hr	114.4	95.47	104.6
Percent Isokinetic	104.6	98.9	

Table C-23. SUMMARY OF ARSENIC TEST DATA -- DC ACID
PLANT INLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	6/21/77	6/22/77	6/23/77	
Test Duration - min.	105	96	96	99
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	58,353	55,189	54,842	56,128
Temperature (°F)	431	408	392	410
Stream (vol. %):				
Water	2.1	5.7	4.9	4.2
CO ₂	0.0	0.0	0.0	0.0
O ₂	17.6	17.2	13.9	16.2
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.9656	0.0810	0.1083	0.3964
gr/acf	0.4882	0.0405	0.0558	0.2006
lb/hr	482.9	38.32	50.89	196.5
Total catch				
gr/dscf	1.0291	0.0997	0.1143	0.4265
gr/acf	0.5203	0.0498	0.0589	0.2158
lb/hr	514.6	47.16	53.73	211.3
Percent Isokinetic	98.5	112.2	106.0	

Table C-24. SUMMARY OF ARSENIC TEST DATA -- DC ACID
PLANT OUTLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	4	Average
Date	6/21/77	6/22/77	6/23/77	6/24/77	
Test Duration - min.	132	132	132	132	132
Charge Rate - ton/hr	a	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a	a
<u>Stack Effluent</u>					
Flow rate (dscfm)	68,108	66,574	66,214	64,643	65,429
Temperature (°F)	147	147	151	156	153
Stream (vol. %):					
Water	0.0	0.0	0.0	0.0	0.0
CO ₂	0.0	0.0	0.0	0.0	0.0
O ₂	17.6	16.0	13.6	11.7	14.7
SO ₂	a	a	a	a	a
<u>Emissions - Arsenic</u>					
Probe, cyclone, and filter catch					
gr/dscf	0.0001	0.0008	0.0005	0.0001	0.0004
gr/acf	0.0001	0.0006	0.0004	0.0001	0.0003
lb/hr	0.043	0.452	0.267	0.050	0.203
Total catch					
gr/dscf	0.0001	0.0014	0.0005	0.0002	0.0005
gr/acf	0.0001	0.0010	0.0004	0.0001	0.0004
lb/hr	0.048	0.783	0.277	0.085	0.298
Percent Isokinetic	73.0	76.2	96.4	97.4	

Table C-25. SUMMARY OF ARSENIC TEST DATA -- CONVERTER BUILDING
BAGHOUSE INLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/18/78	1/19/78	1/23/78	
Test Duration - min.	101	100	100	100
Charge Rate - ton/hr	41.7	32.7	37.1	37.2
Arsenic Rate - lb/hr	212.0	116.1	165.2	164.4
<u>Stack Effluent</u>				
Flow rate (dscfm)	521,956	528,463	506,479	527,497
Temperature (°F)	100	97	123	107
Stream (vol. %):				
Water	1.0	0.4	1.1	0.8
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00270	0.00090	0.00067	0.00142
gr/acf	0.00240	0.00082	0.00058	0.00123
lb/hr	12.11	4.28	2.88	6.42
Total catch				
gr/dscf	0.00272	0.00091	0.00067	0.00143
gr/acf	0.00242	0.00083	0.00058	0.00128
lb/hr	12.12	4.33	2.90	6.45
Percent Isokinetic	95.0	94.2	93.8	

Table C-26. SUMMARY OF ARSENIC TEST DATA -- CONVERTER BUILDING
BAGHOUSE OUTLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/18/78	1/19/78	1/23/78	
Test Duration - min.	160	160	200	173
Charge Rate - ton/hr	41.7	32.7	37.1	37.2
Arsenic Rate - lb/hr	212.0	116.1	165.2	164.4
<u>Stack Effluent</u>				
Flow rate (dscfm)	437,609	526,565	490,455	491,062
Temperature (°F)	101	99	124	108
Stream (vol. %):				
Water	0.0	0.7	1.3	0.7
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00017	0.000005	0.000006	0.00006
gr/acf	0.00015	0.000005	0.000005	0.00005
lb/hr	0.672	0.025	0.026	0.241
Total catch				
gr/dscf	0.00017	0.000010	0.000007	0.00006
gr/acf	0.00015	0.000009	0.000006	0.00005
lb/hr	0.672	0.040	0.027	0.246
Percent Isokinetic	105.7	101.1	102.6	

Table C-27. SUMMARY OF PARTICULATE TEST DATA --
CONVERTER BUILDING BAGHOUSE INLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/17/78	1/18/78	1/21/78	
Test Duration - min.	105	100	100	102
Charge Rate - ton/hr	a	41.7	43.8	42.8
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	435,427	514,279	510,318	486,675
Temperature (°F)	115	113	115	114
Stream (vol. %):				
Water	1.2	1.4	1.4	1.3
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	0.017	0.001	0.001	0.006
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0263	0.0080	0.0309	0.0215
gr/acf	0.0235	0.0202	0.0276	0.0238
lb/hr	98.25	101.9	134.5	111.5
Total catch				
gr/dscf	0.2812	0.2686	0.031	0.2749
gr/acf	0.2507	0.2346	0.027	0.2427
lb/hr	1,049	1,181	134.5	788.0
Percent Isokinetic	109.7	94.5	96.3	

Table C-28. SUMMARY OF PARTICULATE TEST DATA -- CONVERTER BUILDING
BAGHOUSE OUTLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/17/78	1/18/78	1/21/78	
Test Duration - min.	120	160	160	146
Charge Rate - ton/hr	a	41.7	43.8	42.8
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	526,089	471,191	496,907	498,062
Temperature (°F)	114	118	114	115
Stream (vol. %):				
Water	1.0	0.9	1.1	1.0
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	a	a	a	a
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0051	0.0011	0.0005	0.0072
gr/acf	0.0045	0.0010	0.0004	0.0018
lb/hr	22.87	4.45	1.96	9.76
Total catch				
gr/dscf	0.1117	0.1402	0.0081	0.0867
gr/acf	0.0979	0.1260	0.0072	0.0770
lb/hr	503.8	567.4	34.29	368.5
Percent Isokinetic	98.0	97.7	103.7	

Table C-29. SUMMARY OF PARTICULATE TEST DATA -- ROASTER/REVERBERATORY
ESP OUTLET, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/26/78	1/26/78	1/27/78	
Test Duration - min.	144	147	150	147
Charge Rate - ton/hr	64.0	64.0	60.1	62.7
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	200,352	207,295	202,651	203,433
Temperature (°F)	219	205	220	215
Stream (vol. %):				
Water	6.0	6.2	7.3	6.5
CO ₂	3.0	3.0	3.0	3.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	a	a	a	a
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0608	0.0909	0.0411	0.0643
gr/acf	0.0520	0.0787	0.0365	0.0577
lb/hr	104.0	160.7	71.1	112.0
Total catch				
gr/dscf	0.1054	0.1118	0.0553	0.0909
gr/acf	0.0901	0.0968	0.0491	0.0788
lb/hr	180.2	197.7	95.7	157.9
Percent Isokinetic	94.2	90.6	98.8	

Table C-30. SUMMARY OF ARSENIC TEST DATA -- CALCINE DISCHARGE
DUCT, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/24/78	1/24/78	1/24/78	
Test Duration - min.	60	60	60	60
Charge Rate - ton/hr	21.3	21.3	21.3	21.3
Arsenic Rate - lb/hr	83.9	83.9	83.9	83.9
<u>Stack Effluent</u>				
Flow rate (dscfm)	7,705	7,809	7,659	7,724
Temperature (°F)	56	57	61	58
Stream (vol. %):				
Water	0.1	0.4	0.3	0.3
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0049	0.0014	0.0034	0.0032
gr/acf	0.0045	0.0012	0.0030	0.0029
lb/hr	0.326	0.092	0.223	0.214
Total catch				
gr/dscf	0.0050	0.0014	0.0034	0.0033
gr/acf	0.0045	0.0018	0.0031	0.0031
lb/hr	0.332	0.094	0.224	0.217
Percent Isokinetic	93.4	100.7	94.0	

Table C-31. SUMMARY OF PARTICULATE TEST DATA -- CALCINE DISCHARGE
DUCT, ASARCC-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/24/78	1/25/78	1/25/78	
Test Duration - min.	57	60	60	59
Charge Rate - ton/hr	23.5	37.8	37.8	33.0
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	7,932	7,737	7,394	7,687
Temperature (°F)	57	88	96	80
Stream (vol. %):				
Water	0.4	0.3	1.0	0.6
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	0.014	0.005	0.001	0.007
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0512	0.0338	0.0090	0.0313
gr/acf	0.0457	0.0305	0.0080	0.0281
lb/hr	3.49	2.23	0.57	2.09
Total catch				
gr/dscf	0.1861	0.1481	0.3196	0.2179
gr/acf	0.1630	0.1336	0.2861	0.1620
lb/hr	12.70	10.11	20.23	14.34
Percent Isokinetic	96.1	103.6	100.6	

Table C-32. SUMMARY OF ARSENIC TEST DATA -- MATTE TAPPING
DUCT, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/20/78	1/20/78	1/25/78	
Test Duration - min.	240	240	396	292
Charge Rate - ton/hr	69.2	69.2	39.1	59.1
Arsenic Rate - lb/hr	474.2	474.2	176.0	374.8
<u>Stack Effluent</u>				
Flow rate (dscfm)	23,296	26,367	27,418	25,694
Temperature (°F)	105	98	73	92
Stream (vol. %):				
Water	0.3	0.0	0.0	0.1
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0029	0.0026	0.0012	0.0022
gr/acf	0.0024	0.0022	0.0010	0.0019
lb/hr	0.578	0.598	0.288	0.488
Total catch				
gr/dscf	0.0029	0.0027	0.0012	0.00003
gr/acf	0.0025	0.0022	0.0010	0.0019
lb/hr	0.580	0.600	0.288	0.489
Percent Isokinetic	94.5	90.2	86.9	

Table C-33. SUMMARY OF PARTICULATE TEST DATA -- MATTE TAPPING
DUCT, ASARCO-EL PASO SMELTER

Run No.	1	2	3	Average
Date	1/25/78	1/26/78	1/26/78	
Test Duration - min.	389	360	360	369
Charge Rate - ton/hr	39.1	67.6	67.6	58.1
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	26,871	27,370	26,802	27,015
Temperature (°F)	73	82	82	79
Stream (vol. %):				
Water	0.8	0.0	0.0	0.3
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.5	20.5	20.5	20.5
SO ₂	0.006	0.009	0.020	0.012
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0055	0.0193	0.0164	0.0134
gr/acf	0.0047	0.0161	0.0100	0.0103
lb/hr	1.07	3.77	3.09	2.64
Total catch				
gr/dscf	0.0978	0.1632	0.0712	0.1441
gr/acf	0.0836	0.1370	0.1366	0.1191
lb/hr	19.12	32.14	32.27	27.84
Percent Isokinetic	93.7	96.0	91.9	

Table C-34. SUMMARY OF ARSENIC TEST DATA -- SPRAY CHAMBER/BAGHOUSE
INLET-WEST, ANACONDA-ANACONDA SMELTER

Run No.	1	2	3	Average
Date	4/20/77	4/21/77	4/22/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	97	92	92	93.7
Arsenic Rate - lb/hr	2,173	1,490	1,914	1,857
<u>Stack Effluent</u>				
Flow rate (dscfm)	76,274	74,002	77,402	75,893
Temperature (°F)	517	511	466	498
Stream (vol. %):				
Water	11.5	12.2	9.7	11.1
CO ₂	4.0	4.2	0.2	2.8
O ₂	16.4	18.2	19.8	18.1
SO ₂	a	a	a	a
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.4012	0.3550	0.3086	0.3547
gr/acf	0.1551	0.1383	0.1309	0.1414
lb/hr	262.2	225.1	204.7	230.6
Total catch				
gr/dscf	0.4063	0.3706	0.3153	0.3638
gr/acf	0.1571	0.1444	0.1337	0.1450
lb/hr	265.6	235.0	209.1	236.4
Percent Isokinetic	92.9	101.9	100.7	

Table C-35. SUMMARY OF ARSENIC TEST DATA -- SPRAY CHAMBER/BAGHOUSE
INLET-EAST, ANACONDA-ANACONDA SMELTER

Run No.	1	2	3	Average
Date	4/20/77	4/21/77	4/22/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	97	92	92	93.7
Arsenic Rate - lb/hr	2,173	1,490	1,914	1,857
<u>Stack Effluent</u>				
Flow rate (dscfm)	80,193	86,350	86,889	84,477
Temperature (°F)	535	523	475	511
Stream (vol. %):				
Water	12.9	12.8	10.3	12.0
CO ₂	0.8	0.5	0.0	0.4
O ₂	17.4	19.5	19.6	18.8
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.4939	0.3771	0.2559	0.3725
gr/acf	0.1846	0.1442	0.1069	0.1442
lb/hr	339.4	279.0	190.6	267.8
Total catch				
gr/dscf	0.4992	0.3864	0.2690	0.3818
gr/acf	0.1866	0.1477	0.1124	0.1479
lb/hr	343.1	285.9	200.3	274.7
Percent Isokinetic	98.7	96.2	98.5	

Table C-36. SUMMARY OF ARSENIC TEST DATA -- SPRAY CHAMBER/BAGHOUSE
INLET (TOTAL), ANACONDA-ANACONDA SMELTER*

Run No.	1	2	3	Average
Date	4/20/77	4/21/77	4/22/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	97	92	92	93.7
Arsenic Rate - lb/hr	2,173	1,490	1,914	1,857
<u>Stack Effluent</u>				
Flow rate (dscfm)	156,467	160,352	164,291	160,370
Temperature (°F)	526	517	471	505
Stream (vol. %):				
Water	12.2	12.5	10.0	11.6
CO ₂	2.4	2.2	0.1	1.5
O ₂	16.9	18.9	19.7	18.5
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.4588	0.3669	0.2807	0.3595
gr/acf	0.1702	0.1415	0.1182	0.1433
lb/hr	601.6	504.1	395.3	498.4
Total catch				
gr/dscf	0.4539	0.3791	0.2908	0.3733
gr/acf	0.1722	0.1462	0.1224	0.1465
lb/hr	608.7	520.9	409.4	511.1
Percent Isokinetic	c	c	c	

*These data are derived from Tables C-34 and C-35.

Table C-37. SUMMARY OF ARSENIC TEST DATA -- SPRAY CHAMBER/BAGHOUSE
OUTLET, ANACONDA-ANACONDA SMELTER

Run No.	1	2	3	Average
Date	4/20/77	4/21/77	4/22/77	
Test Duration - min.	128	128	128	128
Charge Rate - ton/hr	97	92	92	93.7
Arsenic Rate - lb/hr	2,173	1,490	1,914	1,857
<u>Stack Effluent</u>				
Flow rate (dscfm)	153,594	156,349	164,134	158,026
Temperature (°F)	210	215	214	213
Stream (vol. %):				
Water	19.1	19.3	17.7	18.7
CO ₂	3.6	4.5	3.5	3.9
O ₂	17.0	17.5	16.9	17.1
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0018	0.0023	0.0036	0.0026
gr/acf	0.0009	0.0012	0.0019	0.0013
lb/hr	2.41	3.07	5.00	3.52
Total catch				
gr/dscf	0.0031	0.0041	0.0053	0.0042
gr/acf	0.0016	0.0021	0.0028	0.0015
lb/hr	4.02	5.53	7.45	5.71
Percent Isokinetic	100.4	102.2	98.7	

Table C-38. SUMMARY OF PARTICULATE TEST DATA -- SPRAY CHAMBER/BAGHOUSE
INLET-WEST, ANACONDA-ANACONDA SMELTER

Run No.	1	2	3	Average
Date	4/25/78	4/25/78	4/26/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	86	86	70	80.7
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	77,031	80,363	75,458	77,617
Temperature (°F)	535	546	573	551
Stream (vol. %):				
Water	13.2	12.3	11.2	12.2
CO ₂	2.3	1.4	1.0	1.6
O ₂	16.2	16.9	19.4	17.5
SO ₂	a	a	a	a
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	7.25	6.20	6.40	6.61
gr/acf	2.74	2.34	2.37	2.48
lb/hr	4,786	4,267	4,139	4,397
Total catch				
gr/dscf	7.36	6.25	6.43	6.68
gr/acf	2.78	2.36	2.38	2.51
lb/hr	4,858	4,306	4,161	4,442
Percent Isokinetic	97.4	98.5	100.9	

Table C-39. SUMMARY OF PARTICULATE TEST DATA -- SPRAY CHAMBER/BAGHOUSE
INLET-EAST, ANACONDA-ANACONDA SMELTER

Run No.	1	2	3	Average
Date	4/25/77	4/25/77	4/26/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	86	86	70	80.7
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	85,140	81,352	85,669	84,054
Temperature (°F)	541	555	577	558
Stream (vol. %):				
Water	11.4	12.2	13.5	12.4
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.1	19.4	19.6	19.7
SO ₂	a	a	a	a
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	5.72	5.67	5.93	5.78
gr/acf	2.20	2.13	2.13	2.15
lb/hr	4,170	3,952	4,352	4,162
Total catch				
gr/dscf	5.83	5.76	6.05	5.88
gr/acf	2.24	2.16	2.18	2.19
lb/hr	4,254	4,013	4,442	4,240
Percent Isokinetic	97.9	96.1	98.4	

Table C-40. SUMMARY OF PARTICULATE TEST DATA -- SPRAY CHAMBER/BAGHOUSE
INLET (TOTAL), ANACONDA-ANACONDA SMELTER*

Run No.	1	2	3	Average
Date	4/25/77	4/25/77	4/26/77	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	86	86	70	80.7
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	162,171	161,715	161,127	161,671
Temperature (°F)	538	551	575	555
Stream (vol. %):				
Water	12.3	12.3	12.3	12.3
CO ₂	1.2	0.7	0.5	0.8
O ₂	18.2	18.2	19.5	18.7
SO ₂	a	a	a	a
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	6.45	5.93	6.15	6.18
gr/acf	2.46	2.23	2.24	2.31
lb/hr	8,956	8,219	8,491	8,559
Total catch				
gr/dscf	6.56	6.00	6.23	6.26
gr/acf	2.50	2.26	2.27	2.34
lb/hr	9,112	8,319	8,603	8,682
Percent Isokinetic	c	c	c	

*These data are derived from Tables C-38 and C-39.

Table C-41. SUMMARY OF PARTICULATE TEST DATA -- SPRAY CHAMBER/BAGHOUSE
OUTLET, ANACONDA-ANACONDA SMELTER

Run No.	1	2	3	Average
Date	4/25/77	4/25/77	4/26/77	
Test Duration - min.	128	128	128	128
Charge Rate - ton/hr	86	86	70	80.7
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	170,466	158,252	165,400	164,706
Temperature (°F)	217	218	213	216
Stream (vol. %):				
Water	16.4	19.4	19.7	18.5
CO ₂	4.5	4.8	5.2	4.8
O ₂	18.5	18.2	17.5	18.1
SO ₂	a	a	a	a
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0220	0.0162	0.0228	0.0204
gr/acf	0.0119	0.0085	0.0115	0.0107
lb/hr	32.1	22.0	32.3	28.9
Total catch				
gr/dscf	0.1387	0.0667	0.0288	0.0789
gr/acf	0.0754	0.0349	0.0146	0.0421
lb/hr	202.6	90.4	40.8	112.5
Percent Isokinetic	96.7	99.4	97.7	.

Table C-42. SUMMARY OF ARSENIC TEST DATA -- REVERBERATORY ESP
INLET, PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	7/13/76	7/14/76	7/14/76	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	59.3	72.8	75.4	69.2
<u>Stack Effluent</u>				
Flow rate (dscfm)	58,814	59,583	60,150	59,516
Temperature (°F)	622	602	639	621
Stream (vol. %):				
Water	18.0	18.6	16.0	17.5
CO ₂	a	a	a	a
O ₂	a	a	a	a
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.1076	0.1326	0.1394	0.1265
gr/acf	0.0527	0.0662	0.0673	0.0621
lb/hr	54.3	67.8	71.9	64.7
Total catch				
gr/dscf	0.1172	0.1423	0.1459	0.1351
gr/acf	0.0574	0.0710	0.0704	0.0663
lb/hr	59.1	72.7	75.2	69.0
Percent Isokinetic	154	152	147	

Table C-43. SUMMARY OF ARSENIC TEST DATA -- REVERBERATORY ESP
OUTLET, PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	7/13/76	7/14/76	7/14/76	
Test Duration - min.	120	120	120	120
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	53.7	44.8	51.3	49.9
<u>Stack Effluent</u>				
Flow rate (dscfm)	68,030	66,275	68,738	67,681
Temperature (°F)	595	610	580	595
Stream (vol. %):				
Water	15.3	15.4	13.5	14.7
CO ₂	a	a	a	a
O ₂	a	a	a	a
SO ₂	a	a	a	a
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0603	0.0376	0.0302	0.0427
gr/acf	0.0303	0.0186	0.0154	0.0214
lb/hr	35.2	21.4	17.8	24.8
Total catch				
gr/dscf	0.0919	0.0786	0.0868	0.0858
gr/acf	0.0462	0.0389	0.0442	0.0431
lb/hr	53.6	44.6	51.1	49.8
Percent Isokinetic	145	147	136	

Table C-44. SUMMARY OF ARSENIC TEST DATA -- CONVERTER ESP
INLET NO. 1, PHELPS DODGE-AJO SMELTER

Run No.	1	2*	3	Average
Date	6/13/78		6/15/78	
Test Duration - min.	144		144	144
Charge Rate - ton/hr	17.7		17.7	17.7
Arsenic Rate - lb/hr	38.9		95.6	67.2
<u>Stack Effluent</u>				
Flow rate (dscfm)	28,075		26,638	27,358
Temperature (°F)	379		405	392
Stream (vol. %):				
Water	0.0		4.0	2.0
CO ₂	0.0		0.0	0.0
O ₂	20.0		20.0	20.0
SO ₂	3.83		4.18	4.01
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.000038		0.000010	0.000024
gr/acf	0.000032		0.000008	0.000020
lb/hr	0.0091		0.0022	0.0056
Total catch				
gr/dscf	0.000100		0.000049	0.000073
gr/acf	0.000083		0.000042	0.000063
lb/hr	0.0241		0.0112	0.0062
Percent Isokinetic	126.4		95.2	

*Test run aborted.

Table C-45. SUMMARY OF ARSENIC TEST DATA -- CONVERTER ESP
INLET NO. 2, PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	6/13/78	6/14/78	6/15/78	
Test Duration - min.	144	144	144	144
Charge Rate - ton/hr	17.7	19.7	17.7	18.3
Arsenic Rate - lb/hr	38.9	63.0	95.6	65.8
<u>Stack Effluent</u>				
Flow rate (dscfm)	34,282	28,312	29,265	30,621
Temperature (°F)	389	358	404	384
Stream (vol. %):				
Water	0.3	0.8	0.0	0.4
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	2.59	3.03	7.60	4.41
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.000003	0.000010	0.000005	0.000006
gr/acf	0.000002	0.000009	0.000004	0.000005
lb/hr	0.0095	0.0026	0.0011	0.0044
Total catch				
gr/dscf	0.000003	0.000013	0.000013	0.000010
gr/acf	0.000003	0.000011	0.000011	0.000008
lb/hr	0.0097	0.0031	0.0029	0.0053
Percent Isokinetic	123.2	92.1	99.0	

Table C-46. SUMMARY OF ARSENIC TEST DATA -- CONVERTER ESP
OUTLET (ACID PLANT INLET), PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	6/13/78	6/14/78	6/15/78	
Test Duration - min.	106	111	109	109
Charge Rate - ton/hr	17.7	19.7	17.7	18.3
Arsenic Rate - lb/hr	38.9	63.0	95.6	65.8
<u>Stack Effluent</u>				
Flow rate (dscfm)	41,016	39,021	29,692	36,578
Temperature (°F)	374	360	342	359
Stream (vol. %):				
Water	3.0	2.2	3.7	3.0
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	4.98	2.83	3.99	3.93
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.000033	0.000010	0.000016	0.000020
gr/acf	0.000028	0.000008	0.000014	0.000017
lb/hr	0.0117	0.0033	0.0042	0.0064
Total catch				
gr/dscf	0.000035	0.000011	0.000040	0.000029
gr/acf	0.000030	0.000010	0.000035	0.000025
lb/hr	0.0123	0.0037	0.0104	0.0088
Percent Isokinetic	101.3	102.1	106.8	

Table C-47. SUMMARY OF ARSENIC TEST DATA -- ACID PLANT
OUTLET, PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	6/13/78	6/14/78	6/15/78	
Test Duration - min.	108	108	108	108
Charge Rate - ton/hr	17.7	19.7	17.7	18.3
Arsenic Rate - lb/hr	38.9	63.0	95.6	65.8
<u>Stack Effluent</u>				
Flow rate (dscfm)	47,556	43,862	36,016	42,478
Temperature (°F)	140	164	128	144
Stream (vol. %):				
Water	1.2	0.5	0.0	0.6
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.24	0.12	0.08	0.15
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0000020	0.0000026	0.0000109	0.0000052
gr/acf	0.0000017	0.0000020	0.0000091	0.0000043
lb/hr	0.0009	0.0011	0.0033	0.0018
Total catch				
gr/dscf	0.0000030	0.0000048	0.0000120	0.0000068
gr/acf	0.0000026	0.0000039	0.0000021	0.0000052
lb/hr	0.0013	0.0015	0.0040	0.0022
Percent Isokinetic	100.6	97.4	97.0	

Table C-48. SUMMARY OF ARSENIC TEST DATA -- MATTE TAPPING HOOD
OUTLET, PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	5/10/78	5/11/78	5/12/78	
Test Duration - min.	192	120	120	144
Charge Rate - ton/hr	43.9	40.2	48.1	44.1
Arsenic Rate - lb/hr	776.7	741.3	882.5	800.1
<u>Stack Effluent</u>				
Flow rate (dscfm)	63,758	72,351	69,333	69,056
Temperature (°F)	111	111	120	114
Stream (vol. %):				
Water	0.9	0.9	1.2	1.0
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.02	0.04	0.04	0.03
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00045	0.00076	0.00051	0.00058
gr/acf	0.00042	0.00070	0.00046	0.00052
lb/hr	0.248	0.472	0.300	0.340
Total catch				
gr/dscf	0.00066	0.00082	0.00057	0.00069
gr/acf	0.00062	0.00075	0.00052	0.00063
lb/hr	0.365	0.508	0.344	0.406
Percent Isokinetic	104.2	95.8	97.2	

Table C-49. SUMMARY OF PARTICULATE TEST DATA -- MATTE TAPPING
OUTLET, PHELPS DODGE-AJO SMELTER

Run No.	1	2	Average
Date	5/10/78	5/11/78	
Test Duration - min.	192	120	156
Charge Rate - ton/hr	43.9	40.2	42.0
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	68,930	73,362	71,140
Temperature (°F)	110	112	111
Stream (vol. %):			
Water	0.7	0.3	0.5
CO ₂	0.0	0.0	0.0
O ₂	20.0	20.0	20.0
SO ₂	0.02	0.04	0.03
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	0.0133	0.0226	0.0179
gr/acf	0.0123	0.0207	0.0165
lb/hr	7.89	14.31	11.10
Total catch			
gr/dscf	0.0160	0.0466	0.0313
gr/acf	0.0148	0.0427	0.0288
lb/hr	9.51	29.49	19.50
Percent Isokinetic	108.7	100.1	

Table C-50. SUMMARY OF ARSENIC TEST DATA -- CONVERTER SECONDARY
HOOD OUTLET, PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	5/10/78	5/11/78	5/12/78	
Test Duration - min.	244	120	120	161
Charge Rate - ton/hr	27.3	10.6	28.4	22.1
Arsenic Rate - lb/hr	2.9	1.1	3.0	2.3
<u>Stack Effluent</u>				
Flow rate (dscfm)	85,659	87,444	85,957	86,353
Temperature (°F)	142	162	158	154
Stream (vol. %):				
Water	0.5	1.2	0.6	0.8
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.23	0.34	0.37	0.31
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00247	0.00245	0.00131	0.00208
gr/acf	0.00224	0.00225	0.00121	0.00190
lb/hr	1.813	1.834	0.961	1.536
Total catch				
gr/dscf	0.00251	0.00246	0.00134	0.00211
gr/acf	0.00227	0.00225	0.00125	0.00192
lb/hr	1.837	1.841	0.989	1.556
Percent Isokinetic	101.1	101.1	104.4	

Table C-51. SUMMARY OF PARTICULATE TEST DATA -- CONVERTER SECONDARY
HOOD OUTLET, PHELPS DODGE-AJO SMELTER

Run No.	1	2	3	Average
Date	5/10/78	5/11/78	5/12/78	
Test Duration - min.	244	120	120	161
Charge Rate - ton/hr	27.3	10.6	28.4	22.1
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	86,369	87,708	85,698	86,591
Temperature (°F)	143	163	162	156
Stream (vol. %):				
Water	0.5	0.7	0.5	0.6
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.23	0.34	0.38	0.32
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0756	0.0910	0.0793	0.0820
gr/acf	0.0688	0.0828	0.0835	0.0749
lb/hr	55.93	68.37	58.23	60.85
Total catch				
gr/dscf	0.1016	0.1490	0.1105	0.1204
gr/acf	0.0925	0.1355	0.1025	0.1101
lb/hr	75.16	111.9	81.13	89.41
Percent Isokinetic	101.1	101.1	104.4	

Table C-52. SUMMARY OF ARSENIC TEST DATA -- CONVERTER SECONDARY
HOOD OUTLET, PHELPS DODGE-HIDALGO SMELTER

Run No.	1	2	3	Average
Date	7/25/78	7/26/78	7/26/78	
Test Duration - min.	300	240	240	260
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	69,076	83,346	56,063	69,495
Temperature (°F)	217	208	216	213
Stream (vol. %):				
Water	1.5	2.2	2.2	2.0
CO ₂	0.2	0.2	0.2	0.2
O ₂	20.2	20.2	20.2	20.2
SO ₂	0.38	0.48	1.10	0.65
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00017	0.00010	0.00017	0.00014
gr/acf	0.00014	0.00008	0.00013	0.00012
lb/hr	0.1026	0.0718	0.0807	0.0850
Total catch				
gr/dscf	0.00050	0.00011	0.00020	0.00026
gr/acf	0.00038	0.00009	0.00016	0.00021
lb/hr	0.2947	0.0778	0.0965	0.1563
Percent Isokinetic	85.3	98.6	99.1	

Table C-53. SUMMARY OF ARSENIC TEST DATA -- CALCINE/ROASTER FUGITIVES
BAGHOUSE INLET, PHELPS DODGE-DOUGLAS SMELTER

Run No.	1	2	3	Average
Date	5/3/78	5/4/78	5/4/78	
Test Duration - min.	55	49	38	48
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	0.38	7.96	5.32
<u>Stack Effluent</u>				
Flow rate (dscfm)	29,697	30,359	26,739	28,932
Temperature (°F)	76	72	65	71
Stream (vol. %):				
Water	0.5	0.8	2.0	1.1
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.13	0.21	0.18	0.17
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0000003	0.0000367	0.000193	0.000062
gr/acf	0.0000002	0.0000314	0.000155	0.000062
lb/hr	0.0001	0.0096	0.0424	0.0170
Total catch				
gr/dscf	0.000026	0.000098	0.000281	0.000114
gr/acf	0.000023	0.000083	0.000234	0.000113
lb/hr	0.0067	0.0254	0.0645	0.0322
Percent Isokinetic	97.4	91.7	110.0	

Table C-54. SUMMARY OF ARSENIC TEST DATA -- CALCINE/ROASTER FUGITIVES
BAGHOUSE OUTLET, PHELPS DODGE-DOUGLAS SMELTER

Run No.	1	2	3	Average
Date	5/3/78	5/4/78	5/4/78	
Test Duration - min.	65	42	40	49
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	7.11	a	7.96	5.82
<u>Stack Effluent</u>				
Flow rate (dscfm)	31,539	32,296	31,781	31,872
Temperature (°F)	73	65	79	73
Stream (vol. %):				
Water	1.0	0.9	1.4	1.1
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.08	0.19	0.15	0.14
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.000011	0.000030	0.000069	0.000037
gr/acf	0.000010	0.000026	0.000058	0.000031
lb/hr	0.0030	0.0082	0.0188	0.0100
Total catch				
gr/dscf	0.000105	0.000138	0.000095	0.000107
gr/acf	0.000090	0.000120	0.000079	0.000092
lb/hr	0.0283	0.0381	0.0259	0.0293
Percent Isokinetic	96.5	95.0	90.0	

Table C-55. SUMMARY OF PARTICULATE TEST DATA -- CALCINE/ROASTER FUGITIVES
BAGHOUSE INLET, PHELPS DODGE-DOUGLAS SMELTER

Run No.	1	2	3	Average
Date	5/3/78	5/4/78	5/5/78	
Test Duration - min.	56	47	36	46
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	30,294	29,153	29,036	29,380
Temperature (°F)	69	74	65	69
Stream (vol. %):				
Water	1.2	0.0	0.6	0.6
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.13	0.21	0.18	0.17
<u>Emissions - Particulate</u>				
Probe, cyclone, and filter catch				
gr/dscf	1.766	3.067	2.692	2.508
gr/acf	1.523	2.615	2.282	2.107
lb/hr	458.3	765.8	669.6	631.2
Total catch				
gr/dscf	1.822	3.166	2.925	2.638
gr/acf	1.571	2.699	2.480	2.250
lb/hr	472.9	790.5	727.5	663.6
Percent Isokinetic	96.8	95.0	105.4	

Table C-56. SUMMARY OF PARTICULATE TEST DATA -- CALCINE/ROASTER
FUGITIVES BAGHOUSE OUTLET, PHELPS DODGE-DOUGLAS SMELTER

Run No.	1	2	Average
Date	5/3/78	5/4/78	
Test Duration - min.	65	42	54
Charge Rate - ton/hr	40.1	39.5	39.8
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	29,018	30,985	30,002
Temperature (°F)	73	65	69
Stream (vol. %):			
Water	1.3	0.6	0.95
CO ₂	0.0	0.0	0.0
O ₂	20.0	20.0	20.0
SO ₂	0.09	0.19	0.14
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	0.0031	0.0150	0.0091
gr/acf	0.0026	0.0131	0.0078
lb/hr	0.771	3.98	2.37
Total catch			
gr/dscf	0.0447	0.1927	0.1187
gr/acf	0.0387	0.1655	0.1021
lb/hr	11.11	51.16	31.79
Percent Isokinetic	93.6	87.7	

Table C-57. SUMMARY OF ARSENIC TEST DATA -- CONCENTRATE DRYER SCRUBBER
OUTLET, KENNECOTT-MAGNA SMELTER

Run No.	1	2	3	Average
Date	11/14/78	11/14/78	11/14/78	
Test Duration - min.	90	90	90	90
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	43,489	38,677	47,225	43,130
Temperature (°F)	166	129	118	138
Stream (vol. %):				
Water	18.1	18.2	15.6	17.3
CO ₂	a	a	a	a
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.06	0.07	0.07	0.07
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00003	0.00046	0.00111	0.00047
gr/acf	0.00002	0.00041	0.00084	0.00042
lb/hr	0.0120	0.1531	0.3739	0.1797
Total catch				
gr/dscf	0.00003	0.00047	0.00099	0.00050
gr/acf	0.00003	0.00041	0.00090	0.00045
lb/hr	0.0143	0.1551	0.4029	0.1908
Percent Isokinetic	102.8	98.4	96.5	

Table C-58. SUMMARY OF ARSENIC TEST DATA -- ACID PLANT INLET,
KENNECOTT-MAGNA SMELTER

Run No.	1	2	3	Average
Date	11/6/78	11/7/78	11/8/78	
Test Duration - min.	124	119	120	121
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	47,978	44,725	44,643	45,782
Temperature (°F)	421	476	409	436
Stream (vol. %):				
Water	5.0	3.0	4.0	4.0
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	3.9	2.4	3.0	3.1
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.0034	0.0034	0.0020	0.0029
gr/acf	0.0029	0.0028	0.0018	0.0025
lb/hr	1.397	1.294	0.784	1.158
Total catch				
gr/dscf	0.0055	0.0034	0.0021	0.0037
gr/acf	0.0047	0.0029	0.0018	0.0031
lb/hr	2.278	1.302	0.802	1.461
Percent Isokinetic	97.9	94.1	106.9	

Table C-59. SUMMARY OF ARSENIC TEST DATA -- MATTE TAPPING DUCT,
KENNECOTT-MAGNA SMELTER

Run No.	1	2	3	Average
Date	11/1/78	11/2/78	11/3/78	
Test Duration - min.	70	60	66	65
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	48,968	48,645	43,868	47,162
Temperature (°F)	126	111	119	119
Stream (vol. %):				
Water	1.4	1.0	0.0	0.8
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.09	0.10	0.12	0.10
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00030	0.00052	0.00115	0.00064
gr/acf	0.00026	0.00045	0.00099	0.00056
lb/hr	0.1255	0.2185	0.4341	0.2594
Total catch -				
gr/dscf	0.00036	0.00087	0.00136	0.00085
gr/acf	0.00030	0.00075	0.00117	0.00074
lb/hr	0.1505	0.3641	0.5128	0.3425
Percent Isokinetic	107.3	97.1	103.5	

Table C-60. SUMMARY OF ARSENIC TEST DATA -- SLAG TAPPING DUCT,
KENNECOTT-MAGNA SMELTER

Run No.	1	2	3	Average
Date	11/1/78	11/2/78	11/3/78	
Test Duration - min.	60	120	120	100
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	43,308	40,541	38,914	40,921
Temperature (°F)	73	91	71	78
Stream (vol. %):				
Water	0.3	0.9	1.0	0.7
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.003	0.008	0.004	0.005
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00030	0.00013	0.00005	0.00016
gr/acf	0.00026	0.00011	0.00004	0.00013
lb/hr	0.1119	0.0443	0.0172	0.0578
Total catch				
gr/dscf	0.00036	0.00033	0.00006	0.00025
gr/acf	0.00030	0.00029	0.00005	0.00022
lb/hr	0.1327	0.1152	0.0217	0.0899
Percent Isokinetic	89.9	93.6	97.0	

Table C-61. SUMMARY OF ARSENIC TEST DATA -- CONVERTER FUGITIVES (FULL CYCLE), KENNECOTT-MAGNA SMELTER

Run No.	1	2	3	Average
Date	11/6/78	11/8/78	11/9/78	
Test Duration - min.	188	181	182	184
Charge Rate - ton/hr	a	a	a	a
Arsenic Rate - lb/hr	a	a	a	a
<u>Stack Effluent</u>				
Flow rate (dscfm)	94,684	90,187	92,967	92,613
Temperature (°F)	105	103	61	90
Stream (vol. %):				
Water	0.0	0.8	1.0	0.6
CO ₂	0.0	0.0	0.0	0.0
O ₂	20.0	20.0	20.0	20.0
SO ₂	0.09	0.14	0.33	0.19
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00028	0.00013	0.00044	0.00028
gr/acf	0.00024	0.00011	0.00039	0.00025
lb/hr	0.2262	0.1011	0.3517	0.2263
Total catch				
gr/dscf	0.00034	0.00030	0.00056	0.00040
gr/acf	0.00029	0.00026	0.00050	0.00035
lb/hr	0.2762	0.2364	0.4469	0.3198
Percent Isokinetic	100.8	103.3	93.8	

Table C-62. SUMMARY OF ARSENIC TEST DATA -- ROLLOUT CONVERTER FUGITIVES,
KENNECOTT-MAGNA SMELTER

Run No.	1	2	Average
Date	11/6/78	11/8/78	
Test Duration - min.	88	65	77
Charge Rate - ton/hr	a	a	a
Arsenic Rate - lb/hr	a	a	a
<u>Stack Effluent</u>			
Flow rate (dscfm)	83,303	81,777	82,540
Temperature (°F)	100	106	103
Stream (vol. %):			
Water	1.0	1.0	1.0
CO ₂	a	a	a
O ₂	20.0	20.0	20.0
SO ₂	0.03	0.05	0.04
<u>Emissions - Particulate</u>			
Probe, cyclone, and filter catch			
gr/dscf	0.00019	0.00052	0.00035
gr/acf	0.00016	0.00044	0.00030
lb/hr	0.1342	0.3781	0.2561
Total catch			
gr/dscf	0.00019	0.00057	0.00035
gr/acf	0.00017	0.00048	0.00031
lb/hr	0.1376	0.3971	0.2674
Percent Isokinetic	103.2	99.8	

Table C-63. SUMMARY OF ARSENIC TEST DATA -- VENTURI SCRUBBER
INLET, KENNECOTT-HAYDEN SMELTER

Run No.	1	2	3	4*	Average
Date	12/10/76	12/11/76	12/13/76	12/13/76	
Test Duration - min.	110	135	85	75	101
Charge Rate - ton/hr	61	64	63	64.5	63.2
Arsenic Rate - lb/hr	1.88	1.63	1.65	1.23	1.60
<u>Stack Effluent</u>					
Flow rate (dscfm)	16,971	16,847	19,323	19,011	18,038
Temperature (°F)	636	623	615	621	624
Stream (vol. %):					
Water	26.2	22.4	32.3	27.5	27.1
CO ₂	a	a	a	a	a
O ₂	4.2	4.2	4.2	4.2	4.2
SO ₂	12.4	12.4	12.4	12.4	12.4
<u>Emissions - Arsenic</u>					
Probe, cyclone, and filter catch					
gr/dscf	0.0116	0.0108	0.0097	0.0072	0.0098
gr/acf	0.0044	0.0035	0.0036	0.0027	0.0036
lb/hr	1.69	1.56	1.60	1.17	1.50
Total catch					
gr/dscf	0.0129	0.0113	0.0100	0.0076	0.0104
gr/acf	0.0049	0.0045	0.0037	0.0029	0.0037
lb/hr	1.88	1.63	1.65	1.23	1.60
Percent Isokinetic	146	157	135	126	

*No corresponding test run was performed at the outlet.

Table C-64. SUMMARY OF ARSENIC TEST DATA -- VENTURI SCRUBBER OUTLET,
KENNECOTT-HAYDEN SMELTER

Run No.	1	2	3	Average
Date	12/10/76	12/11/76	12/13/76	
Test Duration - min.	145	145	140	143
Charge Rate - ton/hr	61	64	63	62.7
Arsenic Rate - lb/hr	0.04	0.02	0.02	0.03
<u>Stack Effluent</u>				
Flow rate (dscfm)	15,493	18,918	18,017	17,476
Temperature (°F)	114	111	83	103
Stream (vol. %):				
Water	9.8	9.1	3.8	7.6
CO ₂	a	a	a	a
O ₂	5.4	5.4	5.4	5.4
SO ₂	11.4	11.4	11.4	11.4
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00007	0.00006	0.00004	0.00006
gr/acf	0.00006	0.00005	0.00004	0.00006
lb/hr	0.010	0.010	0.006	0.007
Total catch				
gr/dscf	0.00028	0.00012	0.00014	0.00018
gr/acf	0.00024	0.00010	0.00013	0.00016
lb/hr	0.037	0.019	0.022	0.027
Percent Isokinetic	112	115	101	

Table C-65. SUMMARY OF ARSENIC TEST DATA --ACID PLANT OUTLET,
KENNECOTT-HAYDEN SMELTER

Run No.	1	2	3	Average
Date	12/10/76	12/11/76	12/13/76	
Test Duration - min.	370	265	310	315
Charge Rate - ton/hr	61	64	63	62.7
Arsenic Rate - lb/hr	0.47	0.79	1.46	0.92
<u>Stack Effluent</u>				
Flow rate (dscfm)	74,746	60,114	77,798	70,886
Temperature (°F)	155	158	175	163
Stream (vol. %):				
Water	0.0	0.0	0.0	0.0
CO ₂	a	a	a	a
O ₂	7.7	7.7	7.7	7.7
SO ₂	0.0	0.0	0.0	0.0
<u>Emissions - Arsenic</u>				
Probe, cyclone, and filter catch				
gr/dscf	0.00014	0.00038	0.00020	0.00024
gr/acf	0.00012	0.00033	0.00016	0.00020
lb/hr	0.093	0.203	0.130	0.142
Total catch				
gr/dscf	0.0007	0.0015	0.0022	0.0015
gr/acf	0.0006	0.0013	0.0018	0.0012
lb/hr	0.448	0.773	1.47	0.911
Percent Isokinetic	107	108	95	

Table C-66. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 22--
ROASTER CALCINE DISCHARGE INTO LARRY CARS, ASARCO-TACOMA

Run No.	Date	Observer 1		Observer 2		Mean duration of operation, min:sec	Mean % time emissions observed
		Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed		
1	6/24	1:20	0	1:15	0	1:18	0
2	6/24	2:40	0	2:40	0	2:40	0
3	6/24	1:20	0	1:20	0	1:20	0
4	6/25	1:23	0	1:23	0	1:23	0
5	6/25	1:58	0	1:52	0	1:55	0
6	6/25	1:42	0	1:42	0	1:42	0
7	6/25	1:12	0	1:13	0	1:13	0
8	6/25	1:20	0	1:20	0	1:20	0
9	6/26	2:50	0	2:49	0	2:50	0
10	6/26	1:48	0	1:48	0	1:48	0
11	6/26	2:30	0			2:30	0
12	6/26	1:42	0			1:42	0
13	6/26	3:04	0			3:04	0
Average						1:54	0

Table C-67. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 22--
MATTE TAP PORT AND MATTE LAUNDER, ASARCO-TACOMA

Run ^a Date	Observer 1		Observer 2		Mean	
	Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed
1 6/24	6:24	0	6:36	1	6:30	0.5
2 6/24	6:00	0	6:00	0	6:00	0
3 6/24	4:51	0	4:55	3	4:53	1.5
4 6/24	6:05	0	6:10	0	6:08	0
5 ^b 6/24						
6 6/25	5:28	0			2:58	0
7 6/25	5:22	0	5:22	0	5:22	0
8 6/25	5:36	0	5:36	0	5:36	0
9 6/25	5:08	0	5:10	0	5:09	0
10 6/25	6:02	0	5:33	0	5:48	0
11 6/25	5:12	0	5:13	0	5:13	0
12 6/25			6:37	0	6:37	0
13 6/25	4:50	0	4:53	0	4:52	0
14 6/25	5:23	0	5:22	0	5:23	0
15 6/25	5:17	0	5:18	0	5:18	0
16 ^b 6/25						
17 6/25	5:13	0			5:13	0
18 6/25	5:58	0			5:58	0
Average					5:26	0.13

^aMethod 22 data for corresponding runs at the matte discharge into the ladle are presented in Table C-68.

^bObservations were made only at the matte discharge into the ladle; see Table C-68.

Table C-68. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 22--
MATTE DISCHARGE INTO LADLE, ASARCO-TACOMA

Run ^a	Date	Observer 1		Observer 2		Mean	
		Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed
1	6/24	6:30	0			6:30	0
2	6/24	5:49	0	5:40	0	5:45	0
3	6/24	4:53	0	5:01	0	4:57	0
4	6/24	6:12	0	6:10	0	6:11	0
5	6/24			6:31	0	6:31	0
6 ^b	6/25						
7	6/25	5:09	0	5:02	0	5:06	0
8	6/25	5:21	0	5:28	0	5:25	0
9	6/25	5:02	0	5:03	0	5:03	0
10	6/25	4:29	0	4:32	0	4:31	0
11	6/25	5:12	0	5:13	0	5:13	0
12	6/25	6:16	0			6:16	0
13	6/25	4:43	0	4:45	0	4:44	0
14	6/25	5:13	0	5:15	0	5:14	0
15	6/25	5:15	0	5:09	0	5:12	0
16	6/25	5:41	0	5:50	0	5:46	0
17 ^b	6/25						
18 ^b	6/25						
		Average				5:30	0

^aMethod 22 data for corresponding runs at the matte tap and launder are presented in Table C-67.

^bObservations were made only at the matte tap and launder; see Table C-67.

Table C-69. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 22--
SLAG TAP PORT AND SLAG LAUNDER, ASARCO-TACOMA

Run ^a Date	Observer 1		Observer 2		Mean Duration of operation, min:sec	Mean % Time emissions observed
	Duration of operation, min:sec	% Time emissions observed	Duration of operation, min:sec	% Time emissions observed		
1 6/24	12:25 ^b	98 ^b	12:26 ^b	99 ^b	12:26	
2 6/24	22:00	15	21:36	0	21:43	8
3 6/24	14:07	35 ^b	13:52 ^b	97 ^b	14:07	
4 ^c 6/24	14:10	13			14:10	13
5 6/25	16:44	11			16:44	11
6 ^c 6/25	17:26	2			17:26	2
7 6/26	16:14	1			16:41	1
8 6/26	13:45	0.3			13:45	0
9 6/26	15:45	0			15:45	0
10 6/26	14:29	0			14:29	0
11 ^d						
	Average		Average		15:40	4
	Std. dev.		Std. dev.			11

^aMethod 22 data for corresponding runs at the slag skim discharge point appear in Table C-71.

^bObservations were made at the entire slag tap process line including the slag tap port, slag launder, and slag discharge into ladle; and therefore not included in computing the mean of observations.

^cMethod 9 data for corresponding runs appear in Table C-70.

^dNo data obtained by Method 22.

Table C-70. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 9--
SLAG TAP AND SLAG LAUNDER, ASARCO-TACOMA

Run	Date	Duration of operation, min.	Mean opacity, %	Maximum opacity, %
1	6/25	14.75	1.3	10
2	6/25	18	10.3	30
Average		16.38	6	
Maximum				30

^aEmission data were taken during entire slag tapping operation.

Table C-71. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 22--SLAG TAPPING AT
SLAG DISCHARGE INTO POTS, ASARCO-TACOMA

Run ^{a,b} Date	Observer 1		Observer 2		Mean duration of operation, min:sec	Mean % time emissions observed
	Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed		
1 6/24	12:46	97	12:26	73	12:36	85
2 6/24	21:09	93	21:43	99	21:26	96
3 6/24	14:06	97	13:52	95	13:59	96
4 6/24	14:05	82			14:05	82
5 6/25	16:34	91			16:34	91
6 6/25	17:29	94			17:29	94
7 6/26	15:54	90			15:54	90
8 6/26	13:48	86			13:48	86
9 6/26	15:48	77			15:48	77
10 6/26	14:11	72			14:11	72
11 6/26	14:45	82			14:45	82
Average					15:31	86
Std. dev.						8

^aVisible emissions observation data by EPA Method 9 for corresponding runs are presented in Table C-72.

^bVisible emissions observation data for corresponding runs for the slag tap port and launder are presented in Table C-69.

Table C-72. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 9--
SLAG TAPPING AT SLAG DISCHARGE INTO POTS, ASARCO-TACOMA

Run ^b	Date	Duration of operation, min.	Mean opacity, %	Maximum opacity, %
1	6/24	c		
2	6/24	c		
3	6/24	c		
4	6/25	13.75	22.7	50
5	6/25	16.75	11.3	30
6	6/25	11.75 ^d	16	35
7	6/26	15	14.8	40
8	6/26	15	10.3	20
9	6/26	13	5.5	10
10	6/26	15	3.7	10
11	6/26			
Average		14.32	12	
Maximum				50

^a Emission data were taken during entire slag tapping operation.

^b Method 22 data for corresponding runs appear in Table C-71.

^c No data were obtained by Method 9.

^d Reading started after filling of first slag pot.

Table C-73. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 22--
CONVERTER SLAG RETURN TO REVERBERATORY FURNACE, ASARCO-TACOMA

Run ^a	Date	Observer 1		Observer 2		Observer 3		Mean duration of operation, min:sec	Mean % time emissions observed
		Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed	Duration of operation, min:sec	% time emissions observed		
1	6/24	1:04	100	1:05	89	0:58	100	1:04	96
2	6/24	0:47	97	0:47	96	0:46	100	0:46	98
3	6/24	0:54	100	0:53	100	0:55	100	0:53	100
4	6/25	0:55	100					0:55	100
5	6/25			1:03	100			1:03	100
6	6/25					0:52	100	0:52	100
7	6/25 ^b								
8	6/26	1:04	66					1:04	66
9	6/26	1:00	85					1:00	85
10	6/26	1:15	83					1:15	83
11	6/26	0:55	82	0:41	93			0:48	88
12	6/26								
		Average						0:58	92
		Std. dev.							11

^aVisible emissions observation data by EPA Method 9 for corresponding runs are presented in Table C-74.

^bNo data obtained by Method 22.

Table C-74. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 9--
CONVERTER SLAG RETURN TO REVERBERATORY FURNACE, ASARCO-TACOMA

Run	Date	Observer 1			Observer 2		
		Duration of operation, min.	Average opacity, %	Maximum opacity, %	Duration of operation, min.	Average opacity, %	Maximum opacity, %
1	6/24	a					
2	6/24	a					
3	6/24	a					
4	6/25	1.00	17.5	30	1.00	16	25
5	6/25	1.25	20	40			
6	6/25				1.00	23	35
7	6/25	0.75	23	35	0.75	23	30
8	6/26	1.25	5	10			
9	6/26	1.25	11	20			
10	6/26	1.50	12	20			
11	6/26	1.25	13	20			
12	6/26	0.75	5	10			
average opacity for all readings - 15%							
maximum opacity during all readings - 40%							

^a Data were not obtained by Method 9 on 6/24/80.

Table C-75. VISIBLE EMISSIONS OBSERVATION DATA, EPA METHOD 9--BLISTER DISCHARGE
FROM CONVERTER AT THE TAMANO SMELTER IN JAPAN^{a,b,c}

Opacity, %	Total time equal to or greater than given opacity						
	1st blister discharge		2nd blister discharge		3rd blister discharge		Total blister discharged
	min: sec.	% of total time	min: sec.	% of total time	min: sec.	% of total time	min: sec. % of total time
5	8:00	53	11:30	96	1:00	29	20:30 67
10	5:00	33	8:45	73	0:30	14	14:15 47
15	3:15	22	5:15	44			8:30 28
20	1:30	10	3:15	27			4:45 16
25	0:30	3	2:00	17	0.15	7	2:45 8
30	0:15	2	0.45	6			1:00 3
35			0.15	2			0:15 < 1

^aObservation point: converter secondary hood system.

^bData were based on a total of 30 5-minute observations for three successive blister discharges of the total four blister discharges during one converter cycle. Duration of each of the three discharges observed were 15 minutes, 12 minutes, and 3.5 minutes, respectively.

^cTable C-76 summarizes the observation data into average opacities for each set of 6-minute data.

^dTotal of the three individual blister discharges.

Table C-76. SUMMARY OF AVERAGE OBSERVED OPACITIES FOR BLISTER
DISCHARGE AT THE TAMANO SMELTER IN JAPAN^a

Set No. ^b	Average Opacity ^c ,%
1	6
2	8
3	11
4	10
5	9

^aBased on same observation data used for Table C-75.

^bObservation time for each set was 6 minutes.

^cAverage of all sets is 9 percent.

Table C-77. SUMMARY OF EPA METHOD 9 VISIBLE EMISSIONS DATA--INDIVIDUAL AND TOTAL MATTE CHARGES TO CONVERTER OBSERVED AT THE TAMANO SMELTER IN JAPAN^{a,b,c,d}

Opacity, %	Total time equal to or greater than given opacity											
	1st matte charge		2nd matte charge		3rd matte charge		4th matte charge		Total matte charge			
	min: sec.	% of total time	min: sec.	% of total time	min: sec.	% of total time	min: sec.	% of total time	min: sec.	% of total time	min: sec.	% of total time
5	0:45	43	0:45	60	0:45	43	0		2:15			35
10			0:15	20	0:15	14			0:30			8
25	0:15	14							0:15			4

a) Matte charges 1, 2 and 3 were successive charges; respective charging times for matte charges 1, 2, 3 and 4 were 1.75 min., 1.25 min., 1.75 min., and 1.75 min.

b) Observation point: converter secondary hood system.

c) Data were based on a total of 6.5 minute observation for three successive matte charges at the beginning of one converter cycle and an intermediate matte charging during the cycle. Average duration of each matte charge was 1.5 minutes.

d) Total of the four individual matte charges; average opacity for matte charging, based on total observation, is 3.0 percent.

Table C-78. SUMMARY OF VISIBLE EMISSIONS OBSERVATION DATA--
COPPER BLOW AT THE TAMANO SMELTER IN JAPAN^a

Set No. ^b	Average Opacity, %
1	0
2	0
3	0
4	0

^aObservation point: converter secondary hood system.

^bEach set is based on 6-minute observation.

Table C-79. SUMMARY OF VISIBLE EMISSIONS OBSERVATION DATA--
SLAG BLOW AT THE TAMANO SMELTER IN JAPAN^a

Set No. ^b	Average Opacity, %
1	0
2	0
3	0
4	0
5	0

^aObservation point: converter secondary hood system.

^bEach set represents a 6-minute observation. Set Nos. 1 and 2 are based on the 1st slag blow and set nos. 3 through 5 are based on the second slag blow of the three slag blow total of the complete converter cycle.

Table C-80. SUMMARY OF VISIBLE EMISSIONS
OBSERVATION DATA--CONVERTER SLAG DISCHARGE AT THE
TAMANO SMELTER IN JAPAN^a

Set No. ^b	Average Opacity, %
1	0
2	0

^aObservation point: converter secondary hood system.

^bEach of two consecutive sets of 6-minute observations are made during one slag discharge.

C.11 REFERENCES

1. TRW Environmental Engineering Division. Emission Testing of ASARCO Copper Smelter, Tacoma, Washington. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-12. April 1979.
2. Katari, V., et. al. Trip for ASARCO Copper Smelter, Tacoma, Washington, during June 24 to 26, 1980. Pacific Environmental Services, Incorporated. July 14, 1980. p. 7.
3. Harris, D.L., Monsanto Research Corporation. Air Pollution Emission Test, ASARCO Copper Smelter, El Paso, Texas. U.S. Environmental Protection Agency. EMB Report No. 77-CUS-6. June 20-30, 1977.
4. TRW Environmental Engineering Division. Air Pollution Emission Test. ASARCO Copper Smelter, El Paso, Texas. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-7. April 5, 1978.
5. Harris, D.L., Monsanto Research Corporation. Air Pollution Emission Test, Anaconda Mining Company, Anaconda, Montana. U.S. Environmental Protection Agency. EMB Report No. 77-CUS-5. April 18-26, 1977.
6. Radian Corporation. Arsenic Emissions from an Electrostatic Precipitator of the Phelps-Dodge Copper Smelter in Ajo, Arizona. U.S. Environmental Protection Agency. EPA Contract No. 68-02-13-19. April 4, 1977.
7. Rooney, T., TRW Environmental Engineering Division. Emission Test Report (Acid Plant). Phelps-Dodge Copper Smelter, Ajo, Arizona. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-11. March 1979.
8. Rooney, T., TRW Environmental Engineering Division. Emission Test Report. Phelps-Dodge Copper Smelter, Ajo, Arizona. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-9. February 1979.
9. Rooney, T., TRW Environmental Engineering Division. Emission Testing of Phelps-Dodge Copper Smelter, Playas, New Mexico. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-10. March 1979.
10. Rooney, T., TRW Environmental Engineering Division. Emission Testing of Phelps-Dodge Copper Smelter, Douglas, Arizona. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-9. February 1979.
11. TRW Environmental Engineering Division. Emission Testing of Kennecott Copper Smelter, Magna, Utah. U.S. Environmental Protection Agency. EMB Report No. 78-CUS-13. April 1979.

12. Larkin, R. and J. Steiner. Acurex Corporation/Aerotherm Division. Arsenic Emissions at Kennecott Copper Corporation, Hayden, Arizona. U.S. Environmental Protection Agency. EPA Report No. 76-NFS-1. May 1977.
13. Katari, V. and I.J. Weisenberg. Trip Report--Visit to Hibi Kyodo Smelting Company's Tamano Smelter during the week of March 10, 1980. Pacific Environmental Services, Incorporated. June 9, 1980. Appendix A.

APPENDIX D

TEST METHODS

TEST METHODS

D-1 EMISSION MEASUREMENT METHODS

At the beginning of the testing program, a literature search was conducted to identify available sampling and analytical techniques for determining arsenic emissions. The search revealed that most arsenic emissions are in the form of arsenic trioxide and arsenic pentoxide. According to the literature, the most commonly used arsenic sampling method has been filtration; however, a number of reports have indicated that filtration alone is not adequate, even at ambient temperatures, because arsenic trioxide is a potentially volatile material. Since it was decided to determine the amount of arsenic collected as a particulate, the Method 5 train, with back-up impinger collectors, was chosen as the starting point for the arsenic sampling system. Based on the available information, a dilute sodium hydroxide solution was chosen as a collecting solution for the impingers. This, however, presented a problem since many of the gas streams to be sampled had very high concentrations of sulfur dioxide (SO_2), some as high as 3.5 percent. Therefore, a series of impingers containing hydrogen peroxide was placed between the filter and the first impinger containing

sodium hydroxide to remove the SO_2 . This was the configuration for the "working train" used during the first four field tests.

Analytical methods for arsenic were better defined in the literature. The most commonly-used procedure is a wet chemical method based on arsine generation, but certain metals including copper are interfering agents with this method. Instrumental techniques include atomic absorption, neutron activation, and x-ray fluorescence. Atomic absorption spectrophotometry (AAS) was chosen as the most promising technique because of its ready availability, familiarity, and low cost; however, arsenic absorbs weakly and only in the extreme ultra-violet area of the spectrum (193.7 nm). At that wavelength, molecular absorption by flame gases and solution species can interfere with arsenic detection. Despite this, conventional AAS can still be used, provided that: (1) the fuel and combustion gas are carefully chosen and nonatomic background correction is used; and (2) arsenic concentrations are relatively high. However, for lower arsenic concentrations, the interference effects necessitate the use of a special, more sensitive technique, such as the hydride generator or the carbon rod (flameless) system. Before testing began, both conventional and special AAS methods were compared and evaluated, in terms of their accuracy, precision, and sensitivity.

During the first two field tests, samples were collected with the working train and analyzed either by conventional or carbon rod AAS depending on the arsenic concentration. The analytical results showed that 95 to 100 percent of the arsenic was collected ahead of the NaOH impingers. In the course of analyzing these samples, the following detailed sample preparation procedure was developed. Solid samples were digested with 0.1 N sodium hydroxide, extracted with concentrated nitric acid, evaporated to dryness, and then redissolved in dilute nitric acid. Liquid samples were treated similarly except that there was no need for the sodium hydroxide digestion step. Advantages of the sample preparation procedure include: (1) reduction of the level of the collected sulfuric acid in the liquid sample fraction; (2) dissolution of the arsenic in the solid samples; and (3) production of a similar solution matrix for all the different sample fractions.

After the second test, questions were raised about the sampling and analytical procedures. First of all, laboratory studies of vaporized arsenic trioxide showed no difference in the arsenic collection efficiency of 0.1 N sodium hydroxide and pure water. These results indicated that the arsenic collection mechanism is condensation and that any condenser would be an effective collector. Consequently, the conventional Method 5 train (with H₂O impingers) was suggested as an alternate to the

working train and simultaneous testing of the two trains was planned for the next facility.

Second, an evaluation of the different AAS techniques for low-concentration uncovered some precision and accuracy problems with the carbon rod method when large quantities of dissolved solids (particularly sulfates) are present. The hydride generator technique, it was found, gives much more precise and accurate results in the presence of dissolved solids. In view of this, it was decided that all future low-concentration arsenic samples (i.e., too low for conventional AA analysis) would be analyzed by the hydride generator method.

Third, concern was expressed that arsenic was being lost in the evaporation step of sample preparation. To investigate this, recovery studies were performed on standard samples. These studies showed that there is no significant loss of arsenic during the evaporation step.

Fourth, additional studies showed that while arsenic trioxide is soluble in alkaline, acid, and neutral solutions, its rate of dissolution is slow except in alkaline solutions. Therefore, the clean-up procedure for future test was modified, to require that the train be rinsed with 0.1 N sodium hydroxide to insure removal of condensed arsenic.

Fifth, a comparison of arsenic extraction techniques indicated that higher arsenic yields (by up to 200 percent) can be

obtained from smelter particulate when a method capable of dissolving the entire sample is used instead of the less rigorous acid extraction procedure. As a result, it was decided that in future tests, filters would be analyzed by both methods, until more conclusive filter extraction data were obtained.

During the third and fourth field tests, the working train was used for sampling, but additional runs were taken during the fifth test using paired trains of the working and alternate procedures. Analysis of the samples from the paired tests showed no significant difference in collection efficiency. Therefore, the final recommendation was to use the alternate train, since it is easier to operate and analyze. During the fifth and final field test, the alternate train was used.

Filters from the third, fourth, and fifth field tests were extracted, using both the total dissolution and acid extraction procedure. The results showed that filters extracted by the less rigorous method could in some cases yield 25 percent less arsenic than if totally dissolved. Based upon these results, the final recommendation was to extract the filters first by the simple acid extraction; then, if any undissolved sample remained, to extract the undissolved solids by the total dissolution method.

D.2 CONTINUOUS MONITORING

There is currently no available method for continuously monitoring arsenic emissions. For purposes of demonstrating proper operation and maintenance of control devices, continuous monitors are available for measuring opacity from baghouses or electrostatic precipitators, and measuring pressure drop across scrubbers. However, these measurements are not necessarily indicators of the magnitude of arsenic emissions and should not be used for compliance determinations. In addition, opacity may not be applicable as an indicator of proper operation and maintenance where baghouses and precipitators are used to control captured fugitive emissions because the uncontrolled particulate is very low in concentration.

The recommended monitoring program for continually assessing arsenic emissions is a periodic application of the performance test Method 108 as recommended in Part D.3 below. This is the only method evaluated at this time for demonstration of compliance with arsenic emissions.

D.3 PERFORMANCE TEST METHODS

The recommended performance test method for arsenic is Method 108. Based on the development work already discussed, the method uses the Method 5 train for sampling, 0.1 N sodium hydroxide for

cleanup, and either conventional or hydride generator AAS for sample analysis. In order to perform Method 108, Methods 1 through 4 must also be used. Subpart A or 40 CFR 60 requires that facilities subject to standards of performance for new stationary sources be constructed so as to provide sampling ports adequate for the applicable test methods, and platforms, access, and utilities necessary to perform testing at those ports.

Sampling costs for performing a test consisting of three Method 108 runs is estimated to range from \$10,000 to \$14,000. If in-plant personnel are used to conduct tests, the costs will be somewhat less.

D.4 REFERENCES

1. Hefflefinger, R.E. and D.L. Chase (Battelle). Analysis of Copper Smelter Samples for Arsenic Content. Prepared for U.S. Environmental Protection Agency. Research Triangle Park, NC. April 1977. 14 p.
2. Haile, D.M. (Monsanto Research Corporation). Final Report on the Development of Analytical Procedures for the Determination of Arsenic from Primary Copper Smelters. Prepared for U.S. Environmental Protection Agency. Research Triangle Park, NC. February 1978. 27 p.
3. Harris, D.L. (Monsanto Research Corporation). Particulate and Arsenic Emission Measurements from a Copper Smelter. Prepared

for the U.S. Environmental Protection Agency. Research Triangle Park, NC. 77-CUS-5. April 1977. 48 p.

4. Harris, D.L. (Monsanto Research Corporation). Particulate and Arsenic Emission Measurements from a Copper Smelter. Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, NC. 77-CUS-6. June 1977. 276 p.

5. TRW, Inc. Emission Testing of Asarco Copper Smelter. Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, NC. 77-CUS-7. April 1978. 150 p.

APPENDIX E

QUANTITATIVE EXPRESSIONS OF PUBLIC CANCER RISKS FROM EMISSIONS OF INORGANIC ARSENIC FROM LOW-ARSENIC PRIMARY COPPER SMELTERS

QUANTITATIVE EXPRESSIONS OF PUBLIC CANCER RISKS FROM EMISSIONS OF INORGANIC ARSENIC FROM LOW-ARSENIC PRIMARY COPPER SMELTERS

E.1 INTRODUCTION

E.1.1 Overview

The quantitative expressions of public cancer risks presented in this appendix are based on (1) a dose-response model that numerically relates the degree of exposure to airborne inorganic arsenic to the risk of getting lung cancer, and (2) numerical expressions of public exposure to ambient air concentrations of inorganic arsenic estimated to be caused by emissions from stationary sources. Each of these factors is discussed briefly below and details are provided in the following sections of this appendix.

E.1.2 The Relationship of Exposure to Cancer Risk

The relationship of exposure to the risk of getting lung cancer is derived from epidemiological studies in occupational settings rather than from studies of excess cancer incidence among the public. The epidemiological methods that have successfully revealed associations between occupational exposure and cancer for substances such as asbestos, benzene, vinyl chloride, and ionizing radiation, as well as for inorganic arsenic, are not readily applied to the public sector, with its increased number of confounding variables, much more diverse and mobile exposed population, lack of consolidated medical records, and almost total absence of historical exposure data. Given such uncertainties, EPA considers it improbable that any association, short of very large increases in cancer, can be verified in the general population with any reasonable certainty by an epidemiological study. Furthermore, as noted by the National Academy of Sciences (NAS)¹, "...when there is exposure to a material, we are not starting at an origin

of zero cancers. Nor are we starting at an origin of zero carcinogenic agents in our environment. Thus, it is likely that any carcinogenic agent added to the environment will act by a particular mechanism on a particular cell population that is already being acted on by the same mechanism to induce cancers." In discussing experimental dose-response curves, the NAS observed that most information on carcinogenesis is derived from studies of ionizing radiation with experimental animals and with humans which indicate a linear no-threshold dose-response relationship at low doses. They added that although some evidence exists for thresholds in some animal tissues, by and large, thresholds have not been established for most tissues. NAS concluded that establishing such low-dose thresholds "...would require massive, expensive, and impractical experiments ..." and recognized that the U.S. population "...is a large, diverse, and genetically heterogeneous group exposed to a large variety of toxic agents." This fact, coupled with the known genetic variability to carcinogenesis and the predisposition of some individuals to some form of cancer, makes it extremely difficult, if not impossible, to identify a threshold.

For these reasons, EPA has taken the position, shared by other Federal regulatory agencies, that in the absence of sound scientific evidence to the contrary, carcinogens should be considered to pose some cancer risk at any exposure level. This no-threshold presumption is based on the view that as little as one molecule of a carcinogenic substance may be sufficient to transform a normal cell into a cancer cell. Evidence is available from both the human and animal health literature that cancers may arise from a single transformed cell. Mutation research with ionizing radiation in cell cultures indicates that such a transformation can occur as the result of

interaction with as little as a single cluster of ion pairs. In reviewing the available data regarding carcinogenicity, EPA found no compelling scientific reason to abandon the no-threshold presumption for inorganic arsenic.

In developing the exposure-risk relationship for inorganic arsenic, EPA has assumed that a linear no-threshold relationship exists at and below the levels of exposure reported in the epidemiological studies of occupational exposure. This means that any exposure to inorganic arsenic is assumed to pose some risk of lung cancer and that the linear relationship between cancer risks and levels of public exposure is the same as that between cancer risks and levels of occupational exposure. EPA believes that this assumption is reasonable for public health protection in light of presently available information. However, it should be recognized that the case for the linear no-threshold dose-response relationship model for inorganic arsenic is not quite as strong as that for carcinogens which interact directly or in metabolic form with DNA. Nevertheless, there is no adequate basis for dismissing the linear no-threshold model for inorganic arsenic. The exposure-risk relationship used by EPA represents only a plausible upper-limit risk estimate in the sense that the risk is probably not higher than the calculated level and could be much lower.

The numerical constant that defines the exposure-risk relationship used by EPA in its analysis of carcinogens is called the unit risk estimate. The unit risk estimate for an air pollutant is defined as the lifetime cancer risk occurring in a hypothetical population in which all individuals are exposed continuously from birth throughout their lifetimes (about 70 years) to a concentration of $1 \mu\text{g}/\text{m}^3$ of the agent in the air which they

breathe. Unit risk estimates are used for two purposes: (1) to compare the carcinogenic potency of several agents with each other, and (2) to give a crude indication of the public health risk which might be associated with estimated air exposure to these agents. The comparative potency of different agents is more reliable when the comparison is based on studies of like populations and on the same route of exposure, preferably inhalation.

The unit risk estimate for inorganic arsenic that is used in this appendix was prepared by combining the three different exposure-risk numerical constants developed from three occupational studies.² The unit risk estimate is expressed as a range that reflects the statistical uncertainty associated with combining the three exposure-risk relationships. The methodology used to develop the unit risk estimate is described in E.2 below. EPA is updating its health effects assessment document for inorganic arsenic. A preliminary determination by EPA's health scientists is that the unit risk estimate may change.

E.1.3 Public Exposure

The unit risk estimate is only one of the factors needed to produce quantitative expressions of public health risks. Another factor needed is a numerical expression of public exposure, i.e., of the numbers of people exposed to the various concentrations of inorganic arsenic. The difficulty of defining public exposure was noted by the National Task Force on Environmental Cancer and Health and Lung Disease in their 5th Annual Report to Congress, in 1982.³ They reported that "...a large proportion of the American population works some distance away from their homes and experience different types of pollution in their homes, on the way to and from work, and in the workplace. Also, the American population is quite mobile, and many people move every few years." They also noted the

necessity and difficulty of dealing with long-term exposures because of "...the long latent period required for the development and expression of neoplasia [cancer]..."

EPA's numerical expression of public exposure is based on two estimates. The first is an estimate of the magnitude and location of long-term average ambient air concentrations of inorganic arsenic in the vicinity of emitting sources based on dispersion modeling using long-term estimates of source emissions and meteorological conditions. The second is an estimate of the number and distribution of people living in the vicinity of emitting sources based on Bureau of Census data which "locates" people by population centroids in census tract areas. The people and concentrations are combined to produce numerical expressions of public exposure by an approximating technique contained in a computerized model. The methodology is described in E.3 below.

E.1.4 Public Cancer Risks

By combining numerical expressions of public exposure with the unit risk estimate, two types of numerical expressions of public cancer risks are produced. The first, called individual risk, relates to the person or persons estimated to live in the area of highest concentration as estimated by the dispersion model. Individual risk is expressed as "maximum lifetime risk." As used here, the word "maximum" does not mean the greatest possible risk of cancer to the public. It is based only on the maximum exposure estimated by the procedure used. The second, called aggregate risk, is a summation of all the risks to people estimated to be living within the vicinity (usually within 20 kilometers) of a source and is customarily summed for all the sources in a particular category. The aggregate risk is expressed as incidences of cancer among all of the exposed population after 70 years

of exposure; for statistical convenience, it is often divided by 70 and expressed as cancer incidences per year. These calculations are described in more detail in E.4 below.

There are also risks of nonfatal cancer and of serious genetic effects, depending on which organs receive the exposure. No numerical expressions of such risks have been developed; however, EPA considers all of these risks when making regulatory decisions on limiting emissions of inorganic arsenic.

E.2 THE UNIT RISK ESTIMATE FOR INORGANIC ARSENIC²

E.2.1 The Linear No-Threshold Model for Estimation of Unit Risk Based on Human Data (General)⁴

Very little information exists that can be utilized to extrapolate from high exposure occupational studies to low environmental levels. However, if a number of simplifying assumptions are made, it is possible to construct a crude dose-response model whose parameters can be estimated using vital statistics, epidemiologic studies, and estimates of worker exposures. In human studies, the response is measured in terms of the relative risk of the exposed cohort of individuals compared to the control group. The mathematical model employed assumes that for low exposures the lifetime probability of death from lung cancer (or any cancer), P , may be represented by the linear equation

$$P = A + B_H x \quad (1)$$

where A is the lifetime probability of cancer in the absence of the agent, x is the average lifetime exposure to environmental levels in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), and B_H is the increased probability of cancer associated with each $\mu\text{g}/\text{m}^3$ increase of the agent in air.

If we make the assumption that R , the relative risk of lung cancer for exposed workers, compared to the general population, is independent of the length

or age of exposure but depends only upon the average lifetime exposure, it follows that

$$R = \frac{P}{P_0} = \frac{A + B_H (x_0 + x_1)}{A + B_H (x_0)} \quad (2)$$

or

$$RP_0 = A + B_H (x_0 + x_1) \quad (3)$$

where x_0 = lifetime average exposure to the agent for the general population, x_1 = lifetime average exposure to the agent in the occupational setting, and P_0 = lifetime probability of respiratory cancer applicable with no or negligible arsenic exposure. Substituting $P_0 = A + B_H x_0$ and rearranging gives

$$B_H = P_0 (R - 1)/x_1 \quad (4)$$

To use this model, estimates of R and x_1 must be obtained from the epidemiologic studies. The value P_0 is derived from the age-cause-specific death rates for combined males found in 1976 U.S. Vital Statistics tables using the life table methodology. For lung cancer the estimate of P_0 is 0.036.⁴

E.2.2 The Unit Risk Estimate for Inorganic Arsenic²

As noted in the health effects assessment document⁵ for inorganic arsenic, there are numerous occupational studies which relate increased cancer rates to arsenic exposure. Based on these studies, it is concluded in the health assessment document that there is substantial evidence that inorganic arsenic is a human carcinogen. However, many of these studies are inappropriate for use in developing a unit risk estimate for inorganic arsenic because the route of exposure was not by inhalation or because it was impossible to make a reasonable estimate of the population's lifetime average exposure.

Three studies, Lee and Fraumeni (1969), Ott et al. (1974), and Pinto et al. (1977), contained enough pertinent information to make independent quantitative estimates of human cancer risks due to human exposures to atmospheric arsenic. The crudeness of the exposure estimates in those studies is due to such factors as high variability in the chemical measurement of arsenic, a scarcity of monitoring data, and the necessity of working from summarized data tables presented in the literature rather than complete data on all individuals. However, by accepting the data in spite of their recognized limitations, and making a number of simplifying assumptions concerning dose-response relationships and exposure patterns, it was possible to estimate the carcinogenic potency of arsenic. Using a linear model, it was estimated that the increase in the lung cancer rate per increase of $1 \mu\text{g}/\text{m}^3$ of atmospheric arsenic was 9.4 percent (Pinto et al.), 17.0 percent (Ott et al.), and 3.3 percent (Lee and Fraumeni). The consistency of these estimates is very good considering the relative crudeness of the data upon which they are based. The geometric mean of the rate estimates from the three studies was calculated to be 8.1 percent. Using this value as a best estimate and applying equation 4, one calculates the unit risk estimate of 2.95×10^{-3} per $\mu\text{g}/\text{m}^3$.

If we assume that the linear model and exposure estimates are correct, so that the only source of uncertainty is from combining results from the three different studies, a 95 percent confidence interval for the above unit risk estimate may be obtained. Upper and lower 95 percent confidence limits can be obtained by multiplying the unit risk estimate by about 4 and 0.25, respectively. Thus, the 95 percent statistical confidence limits for the unit risk estimate range from 7.5×10^{-4} to 1.2×10^{-2} .

E.3 QUANTITATIVE EXPRESSIONS OF PUBLIC EXPOSURE TO INORGANIC ARSENIC EMITTED FROM LOW-ARSENIC PRIMARY COPPER SMELTERS

E.3.1 EPA's Human Exposure Model (HEM) (General)

EPA's Human Exposure Model is a general model capable of producing quantitative expressions of public exposure to ambient air concentrations of pollutants emitted from stationary sources. HEM contains (1) an atmospheric dispersion model, with included meteorological data, and (2) a population distribution estimate based on Bureau of Census data. The only input data needed to operate this model are source data, e.g., plant location, height of the emission release point, and temperature of the offgases. Based on the source data, the model estimates the magnitude and distribution of ambient air concentrations of the pollutant in the vicinity of the source. The model is programmed to estimate these concentrations within a radial distance of 20 kilometers from the source. If other radial distances are preferred, an over-ride feature allows the user to select the distance desired. The selection of 20 kilometers as the programmed distance is based on modeling considerations, not on health effects criteria or EPA policy. The dispersion model contained in HEM is felt to be reasonably accurate within 20 kilometers. If the user wishes to use a dispersion model other than the one contained in HEM to estimate ambient air concentrations in the vicinity of a source, HEM can accept the concentrations if they are put into an appropriate format.

Based on the radial distance specified, HEM combines numerically the distributions of pollutant concentrations and people to produce quantitative expressions of public exposure to the pollutant.

E.3.1.1 Pollutant Concentrations Near a Source. The dispersion model within the HEM is a gaussian diffusion model that uses the same basic dispersion algorithm as EPA's Climatological Dispersion Model.⁶ The algorithm has been simplified to improve computational efficiency.⁷ The algorithm is evaluated for a representative set of input values as well as actual plant data, and the concentrations input into the exposure algorithm are arrived at by interpolation. Stability array (STAR) summaries are the principal meteorological input to the HEM dispersion model. STAR data are standard climatological frequency-of-occurrence summaries formulated for use in EPA models and available for major U.S. meteorological monitoring sites from the National Climatic Center, Asheville, N.C. A STAR summary is a joint frequency-of-occurrence of wind speed, atmospheric stability, and wind direction, classified according to Pasquill's categories. The STAR summaries in HEM usually reflect 5 years of meteorological data for each of 309 sites nationwide. The model produces polar coordinate receptor grid points consisting of 10 downwind distances located along each of 16 radials which represent wind directions. Concentrations are estimated by the dispersion model for each of the 160 receptors located on this grid. The radials are separated by 22.5-degree intervals beginning with 0.0 degrees and proceeding clockwise to 337.5 degrees. The 10 downwind distances for each radial are 0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 kilometers. The center of the receptor grid for each plant is assumed to be the plant center.

E.3.1.2 The People Living Near A Source. To estimate the number and distribution of people residing within 20 kilometers of each plant, the model contains a slightly modified version of the "Master Enumeration District List--Extended" (MED-X) data base. The data base is broken down

into enumeration district/block group (ED/BG) values. MED-X contains the population centroid coordinates (latitude and longitude) and the 1970 population of each ED/BG in the United States (50 States plus the District of Columbia). For human exposure estimates, MED-X has been reduced from its complete form (including descriptive and summary data) to produce a computer file of the data necessary for the estimation. A separate file of county-level growth factors, based on 1978 estimates of the 1970 to 1980 growth factor at the county level, has been used to estimate the 1980 population for each ED/BG. HEM identifies the population around each plant by using the geographical coordinates of the plant. The HEM identifies, selects, and stores for later use those ED/BGs with coordinates falling within 20 kilometers of plant center.

E.3.1.3 Exposure⁷. The Human Exposure Model (HEM) uses the estimated ground level concentrations of a pollutant together with population data to calculate public exposure. For each of 160 receptors located around a plant, the concentration of the pollutant and the number of people estimated by the HEM to be exposed to that particular concentration are identified. The HEM multiplies these two numbers to produce exposure estimates and sums these products for each plant.

A two-level scheme has been adopted in order to pair concentrations and populations prior to the computation of exposure. The two level approach is used because the concentrations are defined on a radius-azimuth (polar) grid pattern with non-uniform spacing. At small radii, the grid cells are usually smaller than ED/BG's; at large radii, the grid cells are usually larger than ED/BG's. The area surrounding the source is divided into two regions, and each ED/BG is classified by the region in which its centroid lies.

Population exposure is calculated differently for the ED/BG's located within each region. For ED/BG centroids located between 0.1 km and 2.8 km from the emission source, populations are divided between neighboring concentration grid points. There are 96 (6 x 16) polar grid points within this range. Each grid point has a polar sector defined by two concentric arcs and two wind direction radials. Each of these grid points and respective concentrations are assigned to the nearest ED/BG centroid identified from MED-X. Each ED/BG can be paired with one or many concentration points. The population associated with the ED/BG centroid is then divided among all concentration grid points assigned to it. The land area within each polar sector is considered in the apportionment.

For population centroids between 2.8 km and 20 km from the source, a concentration grid cell, the area approximating a rectangular shape bounded by four receptors, is much larger than the area of a typical ED/BG. Since there is an approximate linear relationship between the logarithm of concentration and the logarithm of distance for receptors more than 2 km from the source, the entire population of the ED/BG is assumed to be exposed to the concentration that is logarithmically interpolated radially and arithmetically interpolated azimuthally from the four receptors bounding the grid cell. Concentration estimates for 80 (5 x 16) grid cell receptors at 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source along each of 16 wind directions are used as reference points for this interpolation.

In summary, two approaches are used to arrive at coincident concentration/population data points. For the 96 concentration points within 2.8 km of the source, the pairing occurs at the polar grid points using an apportionment of ED/BG population by land area. For the remaining portions of the grid, pairing occurs at the ED/BG centroids themselves

through the use of log-log and linear interpolation. (For a more detailed discussion of the model used to estimate exposure, see Reference 7.)

E.3.2 Public Exposure to Inorganic Arsenic Emissions from Low-Arsenic Primary Copper Smelters

E.3.2.1 Source Data. Fourteen smelters are included in the analysis.

Table E.1 lists the names and addresses of the plants considered, and Table E.2 lists the plant data used as input to the Human Exposure Model (HEM).

E.3.2.2 Exposure Data. Table E.3 lists, on a plant-by-plant basis, the total number of people encompassed by the exposure analysis and the total exposure. Total exposure is the sum of the products of number of people times the ambient air concentration to which they are exposed, as calculated by HEM. Table E.4 sums, for the entire source category (14 plants), the numbers of people exposed to various ambient concentrations, as calculated by HEM.

Table E-1. IDENTIFICATION OF LOW-ARSENIC PRIMARY COPPER SMELTERS

Plant Number Code	Plant Name and Address
1	ASARCO, Inc. El Paso, TX
2	ASARCO, Inc. Hayden, AZ
3	Kennecott Corp. Hayden, AZ
4	Kennecott Corp. Hurley, NM
5	Kennecott Corp. McGill, NV
6	Kennecott Corp. Garfield, UT
7	Phelps-Dodge Corp. Morenci, AZ
8	Phelps-Dodge Corp. Douglas, AZ
9	Phelps-Dodge Corp. Ajo, AZ
10	Phelps-Dodge Corp. Hidalgo, NM
11	Copper Range Co. White Pine, MI
12	Magma Copper San Manuel, AZ
13	Inspiration Consolidated Copper Co. Miami, AZ
14	Tennessee Chemical Co. Copperhill, TN

Table E-2. Input Data to Exposure Model Low-Arsenic Primary Copper Smelters
(Assuming Baseline Controls)

Plant	(Emission Point)	Latitude (Degrees Minutes Seconds)	Longitude (Degrees Minutes Seconds)	Arsenic Emission Rate (Kg/yr)	Emission Point Elevation (Meters)	Emission Point Diameter (Meters)	Emission Point Cross Sectional Area (m ²)	Emission Point Gas Exit Velocity m/sec	Emission Point Gas Temp. (°K)	Emission Point Type
1	1	314659	1063126	260	31	1.7	84	14.8	339	Stack
	2			15,130	252	4.9	3,606	19.6	366	Stack
	3			344	40	2.7	110	7.4	337	Stack
	4			24,500	30.5	---	3,720	0.8	298	Vent
	5			390	30.5	1.4	1,500	20.3	---	Vent
	6			705	0	---	---	---	---	Fugitive
2	1	330028	1104559	1,720	61	3.0	325	2.1	352	Stack
	2			29,240	30.5	---	4,200	0.8	298	Vent
	3			1,665	30.5	5.2	6,300	6.7	339	Stack
	4			1,380	0	---	---	---	---	Fugitive
3	1	330041	1104649	430	30.5	2.4	84	12.5	352	Stack
	2			27,520	183	5.2	1,685	5.2	533	Stack
	3			6,450	30.5	---	4,650	0.8	298	Vent
	4			851	30.0	2.0	1,750	20.3	298	Stack
	5			95	0	---	---	---	---	Fugitive
4	1	324156	1080719	3.4	61	3.0	325	2.3	352	Stack
	2			0.9	61	3.1	325	5.6	352	Stack
	3			464	30.5	---	6,300	0.8	298	Vent
	4			108	155	7.9	1,430	9.8	298	Stack
	5			21	0	---	---	---	---	Fugitive
5	1	392433	1144612	394,000	229	4.7	2,725	20.4	422	Stack
	2			46,000	30.5	---	3,140	0.8	298	Vent
	3			4,025	30.5	2.0	1,300	20.3	298	Stack
	4			450	0	---	---	---	---	Fugitive
6	1	404315	1121153	21,130	365	7.3	9,140	11.3	339	Stack
	2			3,870	30.5	---	4,800	0.8	298	Vent
	3			200	0	---	---	---	---	Fugitive
7	1	330403	1092030	520	184	9.1	2,200	0.24	352	Stack
	2			3,555	184	9.1	2,200	3.8	352	Stack
	3			4,820	30.5	---	11,200	0.8	298	Vent
	4			90	0	---	---	---	---	Fugitive
8	1	312048	1093520	18,920	166	6.7	1,685	10.9	505	Stack
	2			19,280	172	5.5	1,770	4.7	505	Stack
	3			4,300	30.5	---	3,490	0.8	298	Vent
	4			4,360	0	---	---	---	---	Fugitive
9	1	322159	1125113	33,140	110	4.6	846	4.8	352	Stack
	2			1,810	30.5	---	3,720	0.8	298	Vent
	3			60	0	---	---	---	---	Fugitive
10	1	314558	1083144	640	61	3.0	325	2.4	352	Stack
	2			1,315	76	3.5	520	3.7	352	Stack
	3			140	30.5	---	3,600	0.8	298	Vent
	4			1,260	183	5.5	2,000	7.1	339	Stack
	5			20	0	---	---	---	---	Fugitive
11	1	464606	0893318	1,720	154	4.6	1,295	6.0	494	Stack
	2			344	30.5	---	3,255	0.8	298	Vent
	3			48	30.5	2.0	3,800	20.3	298	Stack
	4			5	0	---	---	---	---	Fugitive
12	1	323658	1103723	11,180	155	6.1	2,100	8.4	519	Stack
	2			13	61	3.0	325	6.2	325	Stack
	3			13	61	3.0	325	6.2	325	Stack
	4			516	30.5	---	4,200	0.8	298	Vent
	5			81	30.5	2.0	5,250	19.0	298	Vent
	6			9	0	---	---	---	---	Fugitive
13	1	332443	1105058	782	61	3.1	325	7.1	327	Stack
	2			6,880	30.5	---	6,000	0.8	298	Vent
	3			859	30.5	2.0	1,750	10.5	298	Stack
	4			130	0	---	---	---	---	Fugitive
14	1	345946	0842243	0	61	3.0	325	9.0	352	Stack
	2			0	76.2	3.0	520	10.7	352	Stack
	3			80	24	2.0	96	20.3	298	Stack
	4			690	30.5	---	2,400	0.8	298	Vent
	5			9	0	---	---	---	---	Fugitive

*This is the vertical cross sectional area of the emission point to the mean wind direction for purpose of calculating downwash.

Table E-3. TOTAL EXPOSURE AND NUMBER OF PEOPLE EXPOSED
(LOW-ARSENIC PRIMARY COPPER SMELTERS)*

Plant	Total Number of People Exposed	Total Exposure (People - $\mu\text{g}/\text{m}^3$)
1	435,000	6840
2	8,700	580
3	8,700	160
4	19,400	11
5	4500	590
6	79,200	62
7	9,000	80
8	19,000	290
9	9,000	521
10**	300	<1
11	3,000	4
12	12,000	37
13	22,000	370
14	21,000	35

* A 20-kilometer radius was used for the analysis of exposure for the low-arsenic primary copper smelters.

** EPA knows that a small town was built after 1970 within the 20-kilometer radius of this plant. Since the population data base contained in the exposure model is based on population locations contained in the 1970 census data, the risk and incidence estimates do not reflect the location of this town.

Table E-4. PUBLIC EXPOSURE FOR LOW-ARSENIC COPPER SMELTERS
AS PRODUCED BY THE HUMAN EXPOSURE MODEL

Concentration Level ($\mu\text{g}/\text{m}^3$)	Population Exposed (Persons)*	Exposure (Persons - $\mu\text{g}/\text{m}^3$)**
5.81	0	3
5.00	0	3
2.5	9	31
1.0	103	162
0.5	588	497
0.25	2127	1000
0.1	10999	2200
0.05	23601	3080
0.025	80564	4940
0.01	273190	7960
0.005	440328	9140
0.0025	516610	9470
0.001	549474	9530
0.0005	620434	9570
0.00025	635576	9580
0.0001	642017	9580
0.00005	649548	9580
0.000025	650245	9580
0.0000148	650245	9580

*Column 2 displays the computed value, rounded to the nearest whole number, of the cumulative number of people exposed to the matching and higher concentration levels found in column 1. For example, 0.5 people would be rounded to 0 and 0.51 people would be rounded to 1.

**Column 3 displays the computed value of the cumulative exposure to the matching and higher concentration levels found in column 1.

E.4 QUANTITATIVE EXPRESSIONS OF PUBLIC CANCER RISKS FROM INORGANIC ARSENIC EMITTED FROM LOW-ARSENIC PRIMARY COPPER SMELTERS

E.4.1 Methodology (General)

E.4.1.1 The Two Basic Types of Risk. Two basic types of risk are dealt with in the analysis. "Aggregate risk" applies to all of the people encompassed by the particular analysis. Aggregate risk can be related to a single source, to all of the sources in a source category, or to all of the source categories analyzed. Aggregate risk is expressed as incidences of cancer among all of the people included in the analysis, after 70 years of exposure. For statistical convenience, it is often divided by 70 and expressed as cancer incidences per year. "Individual risk" applies to the person or persons estimated to live in the area of the highest ambient air concentrations and it applies to the single source associated with this estimate as estimated by the dispersion model. Individual risk is expressed as "maximum lifetime risk" and reflects the probability of getting cancer if one were continuously exposed to the estimated maximum ambient air concentration for 70 years.

E.4.1.2 The Calculation of Aggregate Risk. Aggregate risk is calculated by multiplying the total exposure produced by HEM (for a single source, a category of sources, or all categories of sources) by the unit risk estimate. The product is cancer incidences among the included population after 70 years of exposure. The total exposure, as calculated by HEM, is illustrated by the following equation:

$$\text{Total Exposure} = \sum_{i=1}^N (P_i C_i)$$

where

$\sum$ = summation over all grid points where exposure is calculated,

P_i = population associated with grid point i ,

C_i = long-term average inorganic arsenic concentration at grid point i ,

N = number of grid points to 2.8 kilometers and number of ED/BG
centroids between 2.8 and 20 kilometers of each source.

To more clearly represent the concept of calculating aggregate risk, a
simplified example illustrating the concept follows:

EXAMPLE

This example uses assumptions rather than actual data and uses only
three levels of exposure rather than the large number produced by HEM. The
assumed unit risk estimate is 3×10^{-3} at $1 \mu\text{g}/\text{m}^3$, and the assumed
exposures are:

<u>ambient air concentrations</u>	<u>number of people exposed to given concentration</u>
2 $\mu\text{g}/\text{m}^3$	1,000
1 $\mu\text{g}/\text{m}^3$	10,000
0.5 $\mu\text{g}/\text{m}^3$	100,000

The probability of getting cancer if continuously exposed to the assumed
concentrations for 70 years is given by:

<u>concentration</u>		<u>unit risk</u>		<u>probability of cancer</u>
2 $\mu\text{g}/\text{m}^3$	x	$3 \times 10^{-3}(\mu\text{g}/\text{m}^3)^{-1}$	=	6×10^{-3}
1 $\mu\text{g}/\text{m}^3$	x	3×10^{-3} "	=	3×10^{-3}
0.5 $\mu\text{g}/\text{m}^3$	x	3×10^{-3} "	=	1.5×10^{-3}

The 70 year cancer incidence among the people exposed to these concentrations is given by:

<u>probability of cancer at each exposure level</u>		<u>number of people at each exposure level</u>		<u>cancer incidences after 70 years of exposure</u>
6 x 10 ⁻³	x	1,000	=	6
3 x 10 ⁻³	x	10,000	=	30
1.5 x 10 ⁻³	x	100,000	=	<u>150</u>
TOTAL =				186

The aggregate risk, or total cancer incidence, is 186 and, expressed as cancer incidence per year, is $186 \div 70$, or 2.7 cancers per year. The total cancer incidence and cancers per year apply to the total of 111,000 people assumed to be exposed to the given concentrations.

E.4.1.3 The Calculation of Individual Risk. Individual risk, expressed as "maximum lifetime risk," is calculated by multiplying the highest concentration to which the public is exposed, as reported by HEM, by the unit risk estimate. The product, a probability of getting cancer, applies to the number of people which HEM reports as being exposed to the highest listed concentration. The concept involved is a simple proportioning from the 1 $\mu\text{g}/\text{m}^3$ on which the unit risk estimate is based to the highest listed concentration. In other words:

$$\frac{\text{maximum lifetime risk}}{\text{highest concentration to which people are exposed}} = \frac{\text{the unit risk estimate}}{1 \mu\text{g}/\text{m}^3}$$

E.4.2 Risks Calculated for Emissions of Inorganic Arsenic from Low-Arsenic Primary Copper Smelters

The explained methodologies for calculating maximum lifetime risk and cancer incidences were applied to each low-arsenic primary copper smelter, assuming a baseline level of emissions. A baseline level of emissions means the level of emissions after the application of controls either currently in place or required to be in place to comply with current State or Federal regulations but before application of controls that would be required by a NESHAP.

Table E-5 summarizes the calculated risks. To understand the relevance of these numbers, one should refer to the analytical uncertainties discussed in Section E.5 below.

Table E.5. MAXIMUM LIFETIME RISK AND CANCER INCIDENCE
FOR LOW-ARSENIC PRIMARY COPPER SMELTERS
(Assuming Baseline Controls)

Plant	Maximum Lifetime Risk	Cancer Incidences Per Year	Cancer Incidence (one case in [x] years)
1	$1.1 \times 10^{-3} - 1.8 \times 10^{-2}$	$7.1 \times 10^{-2} - 1.1 \times 10^{-1}$	1 in 14 yrs. - 1 in 1 yrs.
2	$2.3 \times 10^{-3} - 3.6 \times 10^{-2}$	$6.0 \times 10^{-3} - 9.5 \times 10^{-2}$	1 in 200 yrs. - 1 in 10 yrs.
3	$4.3 \times 10^{-4} - 6.9 \times 10^{-3}$	$1.6 \times 10^{-3} - 2.6 \times 10^{-2}$	1 in 600 yrs. - 1 in 40 yrs.
4	$4.1 \times 10^{-5} - 6.6 \times 10^{-4}$	$1.2 \times 10^{-4} - 1.9 \times 10^{-3}$	1 in 9000 yrs. - 1 in 500 yrs.
5	$4.3 \times 10^{-3} - 6.9 \times 10^{-2}$	$6.4 \times 10^{-3} - 1.0 \times 10^{-1}$	1 in 200 yrs. - 1 in 10 yrs.
6	$1.6 \times 10^{-6} - 2.6 \times 10^{-5}$	$6.4 \times 10^{-4} - 1.0 \times 10^{-2}$	1 in 2000 yrs. - 1 in 100 yrs.
7	$1.5 \times 10^{-4} - 2.4 \times 10^{-3}$	$8.2 \times 10^{-4} - 1.3 \times 10^{-2}$	1 in 1000 yrs. - 1 in 80 yrs.
8	$9.4 \times 10^{-4} - 1.5 \times 10^{-2}$	$3.0 \times 10^{-3} - 4.8 \times 10^{-2}$	1 in 300 yrs. - 1 in 20 yrs.
9	$1.5 \times 10^{-4} - 2.5 \times 10^{-3}$	$5.4 \times 10^{-3} - 8.6 \times 10^{-2}$	1 in 200 yrs. - 1 in 10 yrs.
10*	$1.4 \times 10^{-6} - 2.2 \times 10^{-5}$	$5.3 \times 10^{-6} - 8.5 \times 10^{-5}$	1 in 200,000 yrs. - 1 in 10,000 yrs.
11	$1.5 \times 10^{-5} - 2.4 \times 10^{-4}$	$4.3 \times 10^{-5} - 7.0 \times 10^{-4}$	1 in 20,000 yrs. - 1 in 2000 yrs.
12	$3.6 \times 10^{-5} - 5.8 \times 10^{-4}$	$3.8 \times 10^{-4} - 6.1 \times 10^{-3}$	1 in 3000 yrs. - 1 in 200 yrs.
13	$4.8 \times 10^{-4} - 7.7 \times 10^{-3}$	$3.8 \times 10^{-3} - 6.1 \times 10^{-2}$	1 in 300 yrs. - 1 in 20 yrs.
14	$7.1 \times 10^{-5} - 1.1 \times 10^{-3}$	$3.6 \times 10^{-4} - 5.8 \times 10^{-3}$	1 in 3000 yrs. - 1 in 200 yrs.

TOTALS FOR THIS SOURCE CATEGORY

Number of Plants	Total Number of People Exposed (within 20 km)	Highest Individual Risk (For Plant 5)	Cancer Incidences	
			per year	one case in [x] years
14	650,200	$4.3 \times 10^{-3} - 6.9 \times 10^{-2}$ (For Plant 5)	0.1 - 1.6	1 in 10 yrs. - 1 in 1 yrs.

NOTE: The ranges in these quantifications of public health impacts reflect the uncertainty of combining the three different dose-response relationships relevant to the three occupational studies which EPA used as the basis for the development of unit risk estimate.²

*EPA knows that a small town was built after 1970 within the 20-kilometer radius of this plant. Since the population data base contained in the exposure model is based on population locations contained in the 1970 census data, the risk incidence estimates do not reflect the location of this town.

E.5 ANALYTICAL UNCERTAINTIES APPLICABLE TO THE CALCULATIONS OF PUBLIC HEALTH RISKS CONTAINED IN THIS APPENDIX

E.5.1 The Unit Risk Estimate

The procedure used to develop the unit risk estimate is described in Reference 2. The model used and its application to epidemiological data have been the subjects of substantial comment by health scientists. The uncertainties are too complex to be summarized sensibly in this appendix. Readers who wish to go beyond the information presented in the reference should see the following Federal Register notices: (1) OSHA's "Supplemental Statement of Reasons for the Final Rule", 48 FR 1864 (January 14, 1983); and (2) EPA's "Water Quality Documents Availability" 45 FR 79318 (November 28, 1980).

The unit risk estimate used in this analysis applies only to lung cancer. Other health effects are possible; these include skin cancer, hyperkeratosis, peripheral neuropathy, growth retardation and brain dysfunction among children, and increase in adverse birth outcomes. No numerical expressions of risks relevant to these health effects are included in this analysis.

E.5.2 Public Exposure

E.5.2.1 General. The basic assumptions implicit in the methodology are that all exposure occurs at people's residences, that people stay at the same location for 70 years, that the ambient air concentrations and the emissions which cause these concentrations persist for 70 years, and that the concentrations are the same inside and outside the residences. From this it can be seen that public exposure is based on a hypothetical rather than a realistic premise.

It is not known whether this results in an over-estimation or an under-estimation of public exposure.

E.5.2.2 The Public. The following are relevant to the public as dealt with in this analysis:

1. Studies show that all people are not equally susceptible to cancer. There is no numerical recognition of the "most susceptible" subset of the population exposed.
2. Studies indicate that whether or not exposure to a particular carcinogen results in cancer may be affected by the person's exposure to other substances. The public's exposure to other substances is not numerically considered.
3. Some members of the public included in this analysis are likely to be exposed to inorganic arsenic in the air in the workplace, and workplace air concentrations of a pollutant are customarily much higher than the concentrations found in the ambient, or public air. Workplace exposures are not numerically approximated.
4. Studies show that there is normally a long latent period between exposure and the onset of lung cancer. This has not been numerically recognized.
5. The people dealt with in the analysis are not located by actual residences. As explained previously, they are "located" in the Bureau of Census data for 1970 by population centroids of census districts. Further, the locations of these centroids have not been changed to reflect the 1980 census. The effect is that the actual locations of residences with respect to the estimated ambient air concentrations are not known and that the relative

locations used in the exposure model have changed since the 1970 census.

6. Many people dealt with in this analysis are subject to exposure to ambient air concentrations of inorganic arsenic where they travel and shop (as in downtown areas and suburban shopping centers), where they congregate (as in public parks, sports stadiums, and schoolyards), and where they work outside (as mailmen, milkmen, and construction workers). These types of exposures are not numerically dealt with.

E.5.2.3. The Ambient Air Concentrations

The following are relevant to the estimated ambient air concentrations of inorganic arsenic used in this analysis:

1. Flat terrain was assumed in the dispersion model. Concentrations much higher than those estimated would result if emissions impact on elevated terrain or tall buildings near a plant.

2. The estimated concentrations do not account for the additive impact of emissions from plants located close to one another.

3. The increase in concentrations that could result from re-entrainment of arsenic-bearing dust from, e.g., city streets, dirt roads, and vacant lots, is not considered.

4. Meteorological data specific to plant sites are not used in the dispersion model. As explained, HEM uses the meteorological data from the STAR station nearest the plant site. Site-specific meteorological data could result in significantly different estimates, e.g., the estimates of where the higher concentrations occur.

5. With few exceptions, the arsenic emission rates are based on assumptions rather than on emission tests. See the BID for details on each source.

E.6 REFERENCES

1. National Academy of Sciences, "Arsenic," Committee on Medical and Biological Effects of Environmental Pollutants, Washington, D.C., 1977. Docket Number (OAQPS 79-8) II-A-3.
2. The Carcinogen Assessment Group's Final Risk Assessment on Arsenic. OAQPS Docket Number 79-8-II-A-7. May 2, 1980.
3. U.S. EPA, et.al., "Environmental Cancer and Heart and Lung Disease," Fifth Annual Report to Congress by the Task Force on Environmental Cancer and Health and Lung Disease, August 1982.
4. U.S. EPA, "Health Assessment Document for Acrylonitrile," Draft Report from the Office of Health and Assessment, EPA-600/8-82-007, November 1982.
5. U.S. EPA, "An Assessment of the Health Effects of Arsenic," Docket Number (OAQPS 79-8) II-A-5, April 1978.
6. Busse, A.D. and Zimmerman. J.R., "User's Guide for the Climatological Dispersion Model." (Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.) Publication Number EPA-R4-73-024. December 1973.
7. Systems Application, Inc., "Human Exposure to Atmospheric Concentrations of Selected Chemicals." (Prepared for the U.S. Environmental Protection Agency, Research Triangle Park, North Carolina). Volume I, Publication Number EPA-2/250-1, and Volume II, Publication Number EPA-1/250-2.

APPENDIX F

ARSENIC DISTRIBUTION AT U.S. COPPER SMELTERS

ARSENIC DISTRIBUTION AT U.S. COPPER SMELTERS

Appendix F presents information regarding the distribution of arsenic in domestic copper smelters. Information was received in response to requests made by EPA. However, for certain copper smelters, the information received was incomplete. In these cases, assumptions were made regarding the behavior of inorganic arsenic. The bases for these assumptions are discussed for each smelter. Based on the information provided and engineering judgment, inorganic arsenic mass balances were developed for each copper smelter.

F.1 ARSENIC DISTRIBUTION AT ASARCO-E1 PASO

An arsenic mass balance for the ASARCO-E1 Paso smelter is presented in Figure F-1. Data were provided to EPA by ASARCO;¹ however, a few assumptions were necessary to obtain a closed mass balance. The arsenic collection efficiency for the spray chamber and electrostatic precipitator systems treating the roaster and converter offgases is 96 percent, based on review of test data. Also, arsenic collection efficiency for the acid plant treating the roaster and converter offgases is 99 percent. In addition to the dust collected in the roaster and reverberatory furnace collection system, 11 lb/hr of dust collected in the converter collection system is recycled back to the roasters.

F.2 ARSENIC DISTRIBUTION AT ASARCO-HAYDEN

ASARCO is in the process of modernizing the Hayden plant. The existing conventional technology consisting of roaster, reverberatory furnace, and converter equipment is being replaced by INCO flash furnace technology. The arsenic mass balance for the Hayden copper smelter presented in Figure F-2 represents the flash furnace technology. The data on arsenic distributions for the Hayden smelter were available only for the existing smelter configuration. Therefore, an arsenic balance

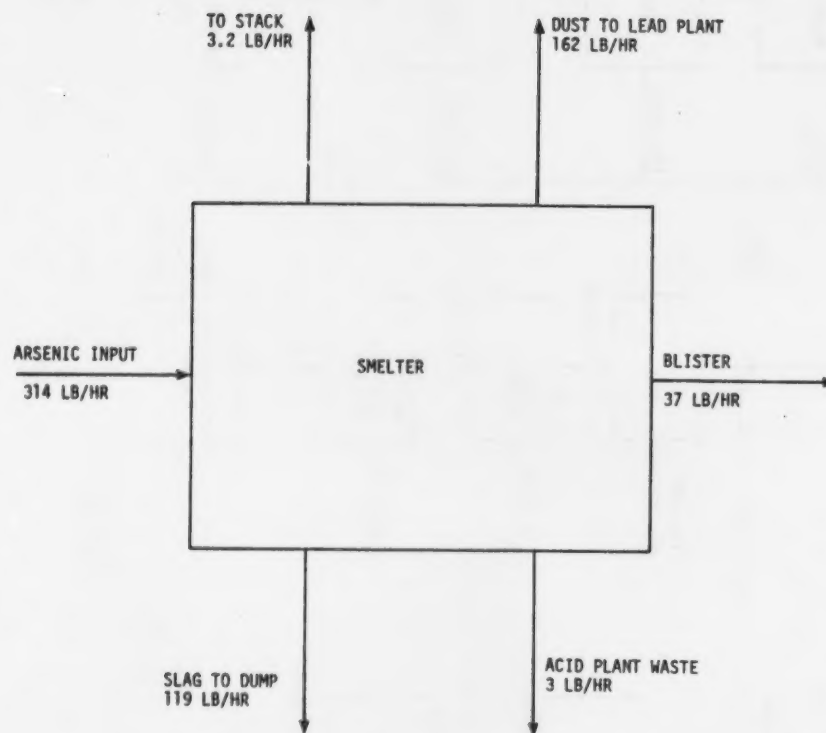


Figure F-1(b). Overall Arsenic Material Balance at ASARCO-El Paso Smelter

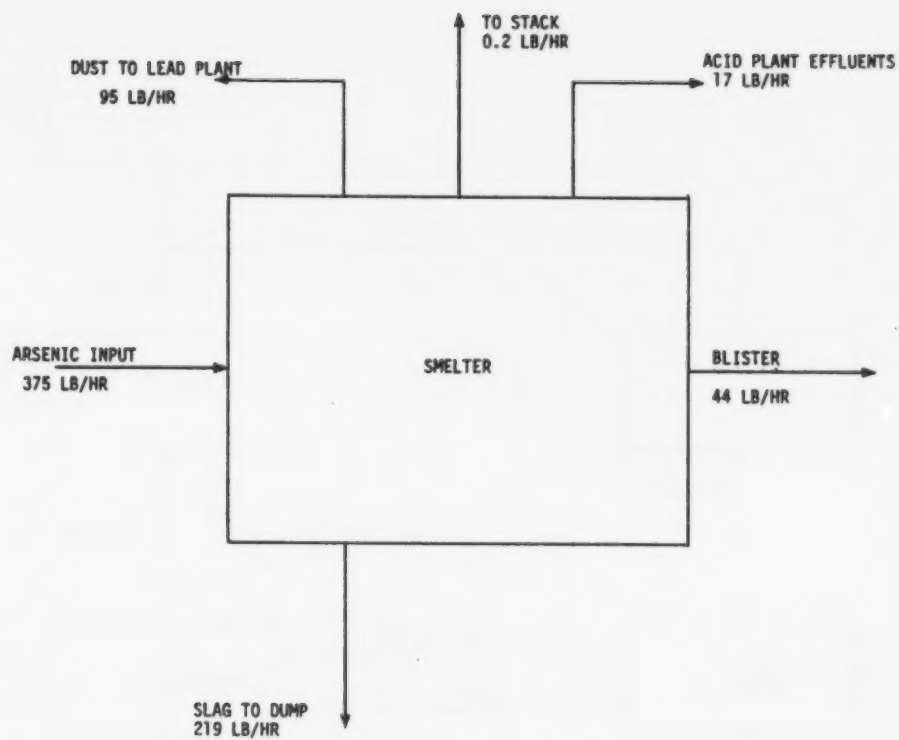


Figure F-2(b). Overall Arsenic Material Balance at ASARCO-Hayden Smelter

is developed for the smelter by using the arsenic input rate to the smelter (375 lb/hr)¹ and the percentages of input arsenic in the various process streams for the flash furnace smelting technology at the Kennecott-Hurley smelter (discussed in Section F.7).²

F.3 ARSENIC DISTRIBUTION AT TENNESSEE CHEMICAL CO.-COPPERHILL

An arsenic mass balance for the Tennessee Chemical Co.-Copperhill smelter is presented in Figure F-3. Tennessee Chemical Company provided flowsheets and information to EPA.³ Based on actual tonnages processed and typical analyses, the actual arsenic input to the smelter was estimated to be 2.9 lb/hr.

F.4 ARSENIC DISTRIBUTION AT INSPIRATION CONSOLIDATED

An arsenic material balance for the Inspiration Consolidated Copper Company smelter located near Miami, Arizona, is presented in Figure F-4. The data were provided to EPA by the company.⁴

Arsenic input to the smelter is 41.1 lb/hr. This is based on 1,495 tpd of concentrate containing 0.033 percent arsenic fed to the electric furnace. Nineteen percent of the arsenic into the smelter is volatilized in the electric furnace and 6 percent is volatilized in the converters. Also, 58 percent of the input arsenic into the smelter is slagged in the electric furnace and 17 percent is slagged in the converters.

F.5. ARSENIC DISTRIBUTION AT KENNECOTT-GARFIELD

An arsenic mass balance for the Kennecott-Garfield smelter is presented in Figure F-5. Mass balance data were provided to EPA by Kennecott Copper Company in response to information requests.^{2,5,6}

The arsenic material balance for the smelter is obtained by combining the arsenic rates of various smelter streams (in flow diagrams provided by Kennecott⁶) with the feed and end product rates provided by the company. The following feed and end product arsenic contents provided by the company are used in the mass balance: total arsenic input - 261 lb/hr; slag tailings - 34 lb/hr; precipitator dust to storage - 123 lb/hr; blister copper - 29 lb/hr; gas cleaning plant effluent - 71 lb/hr; and stack emissions - 4 lb/hr.

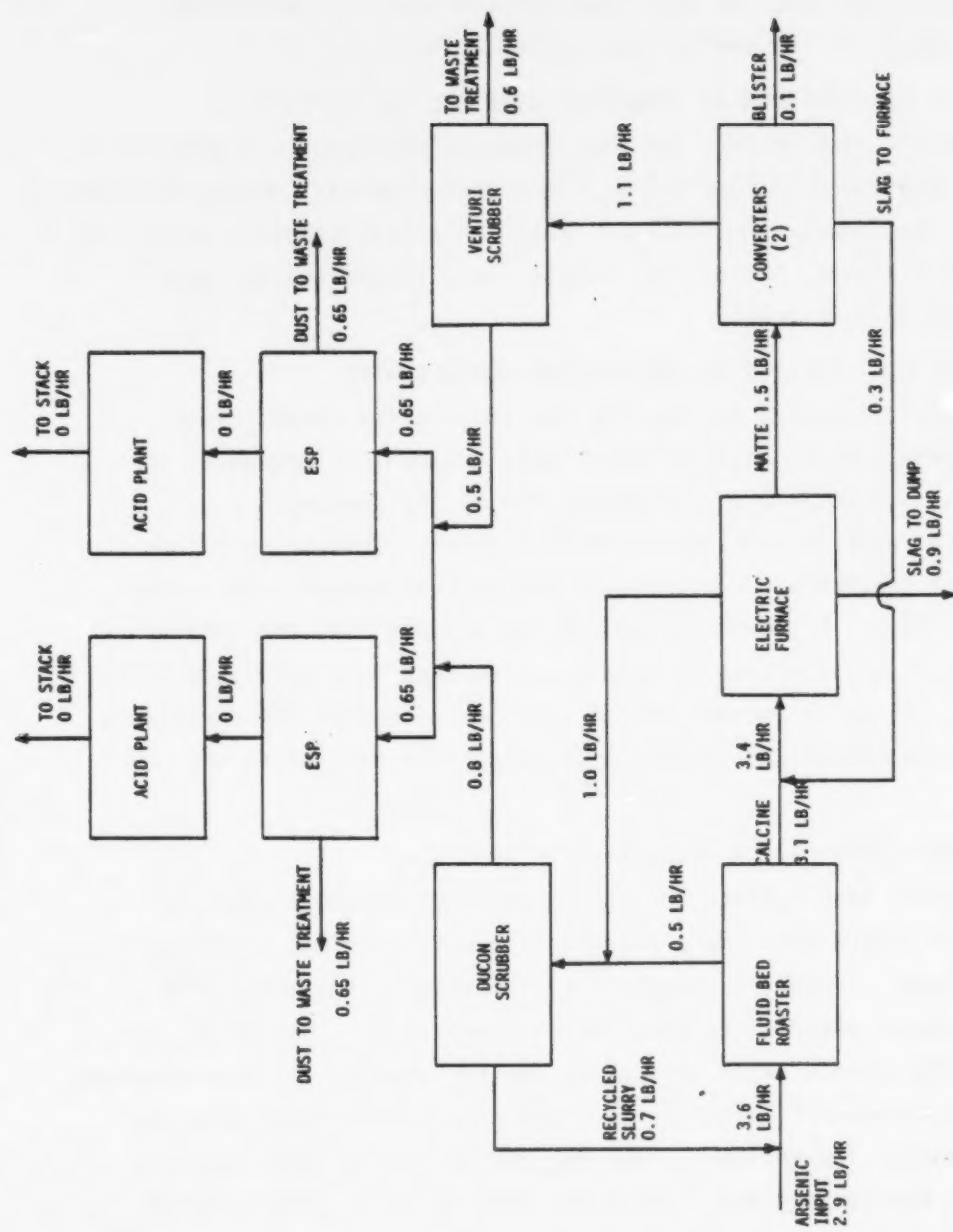


Figure F-3(a). Arsenic Distribution at TN Chemical Co.-
Copperhill Smelter

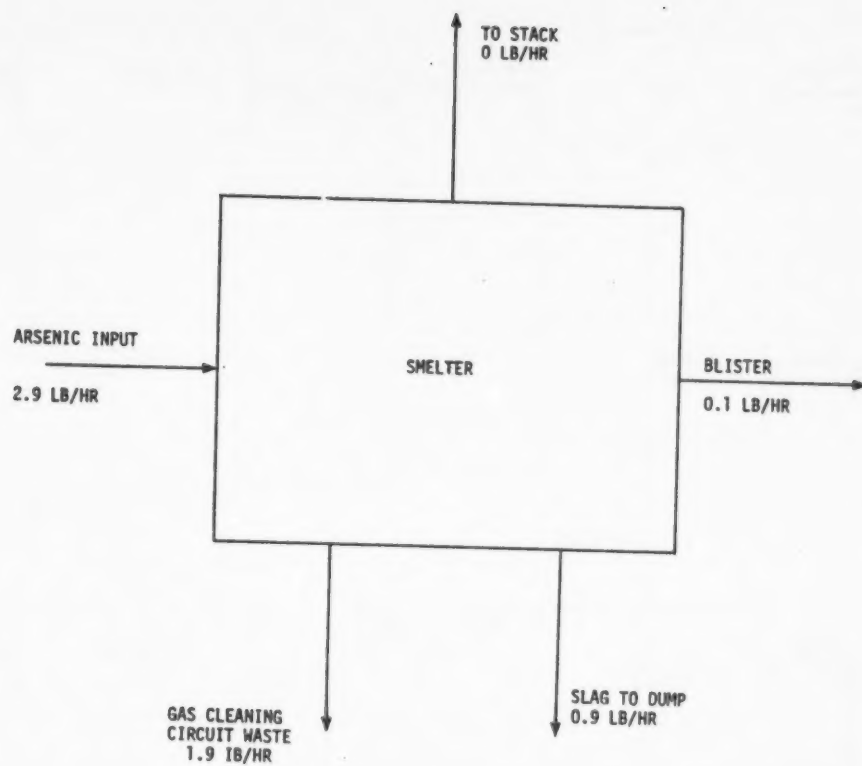


Figure F-3(b). Overall Arsenic Material Balance at
TN Chemical Co.-Copperhill Smelter

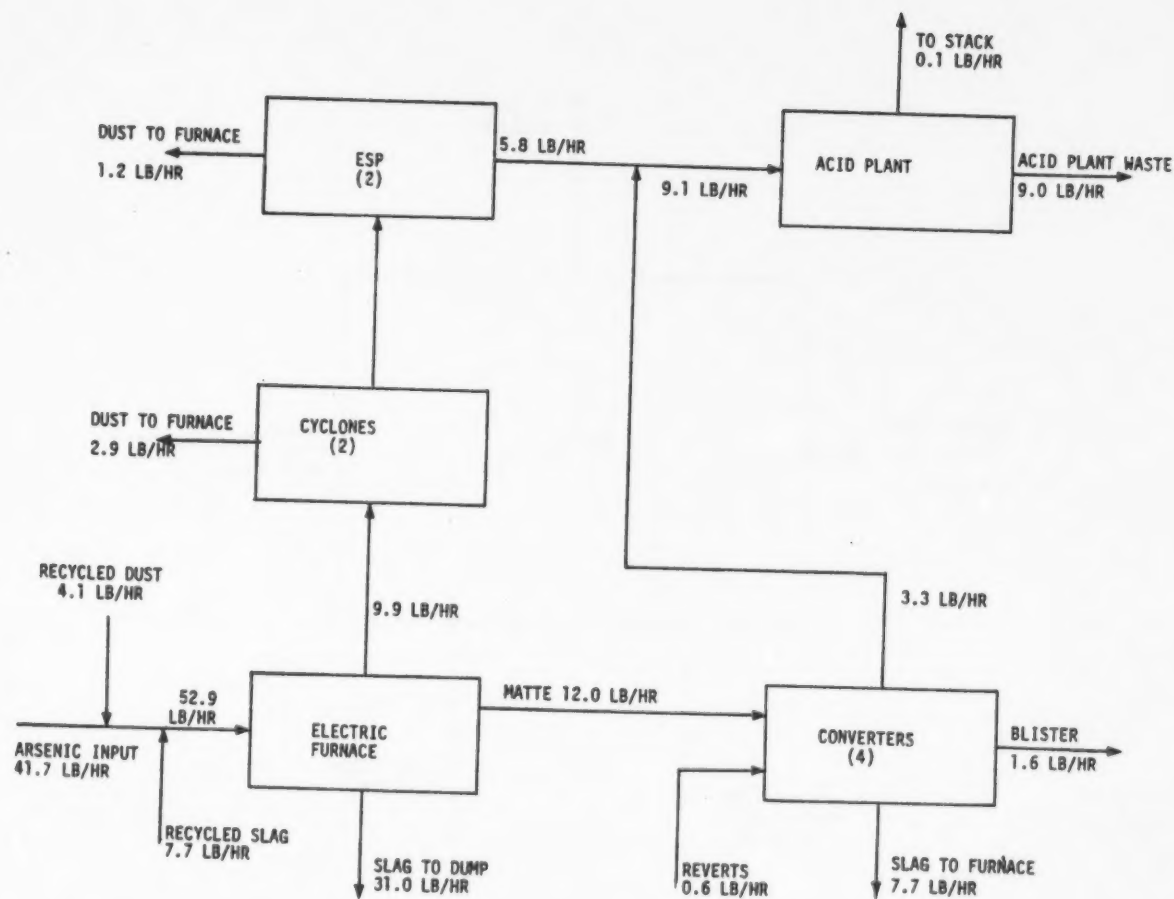


Figure F-4(a). Arsenic Distribution at Inspiration-Miami Smelter

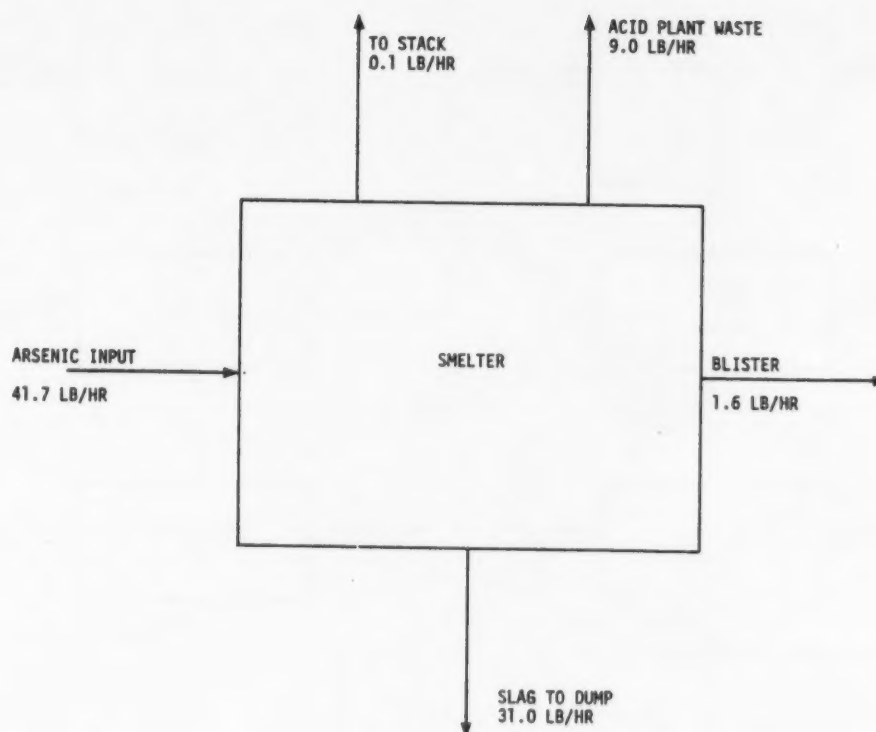


Figure F-4(b). Overall Arsenic Material Balance at Inspiration-Miami Smelter

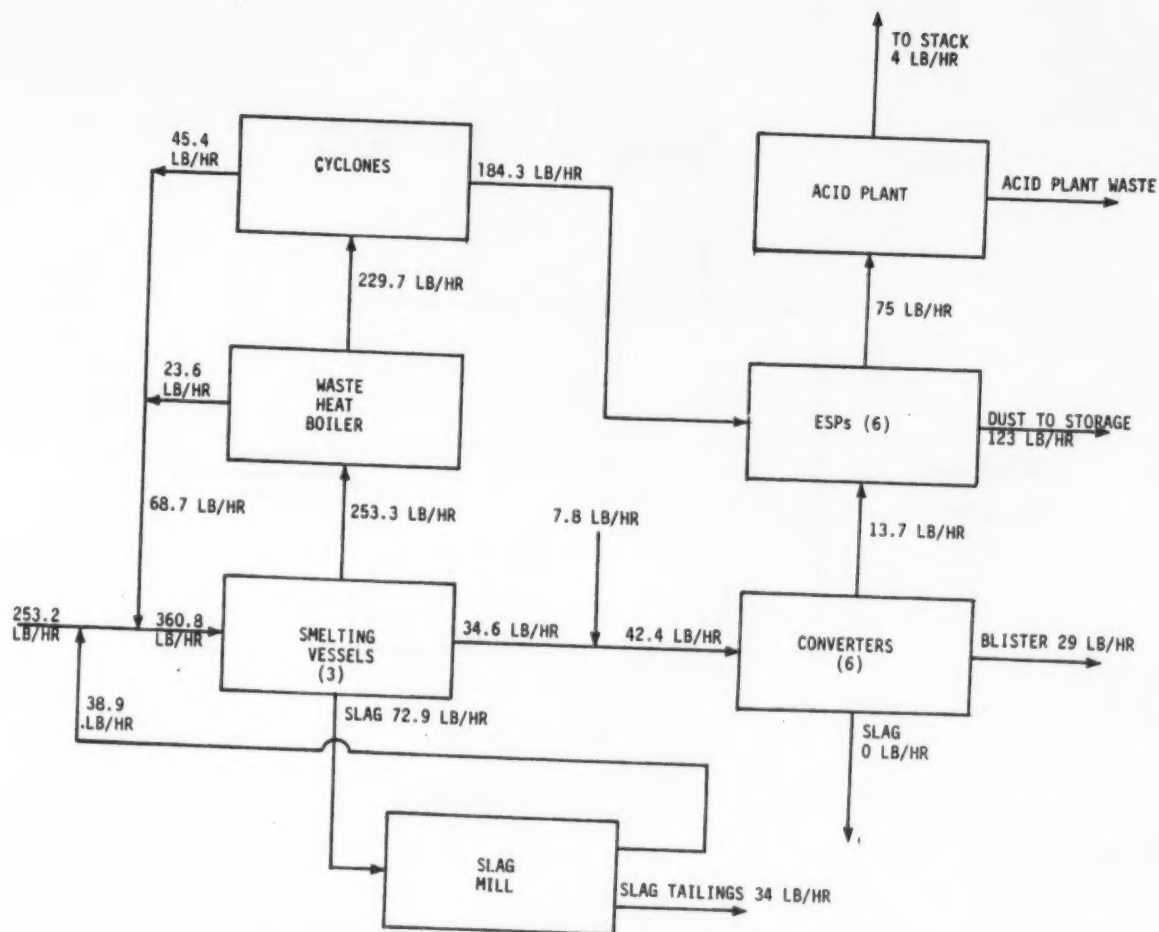


Figure F-5(a). Arsenic Distribution at Kennecott-Garfield Smelter

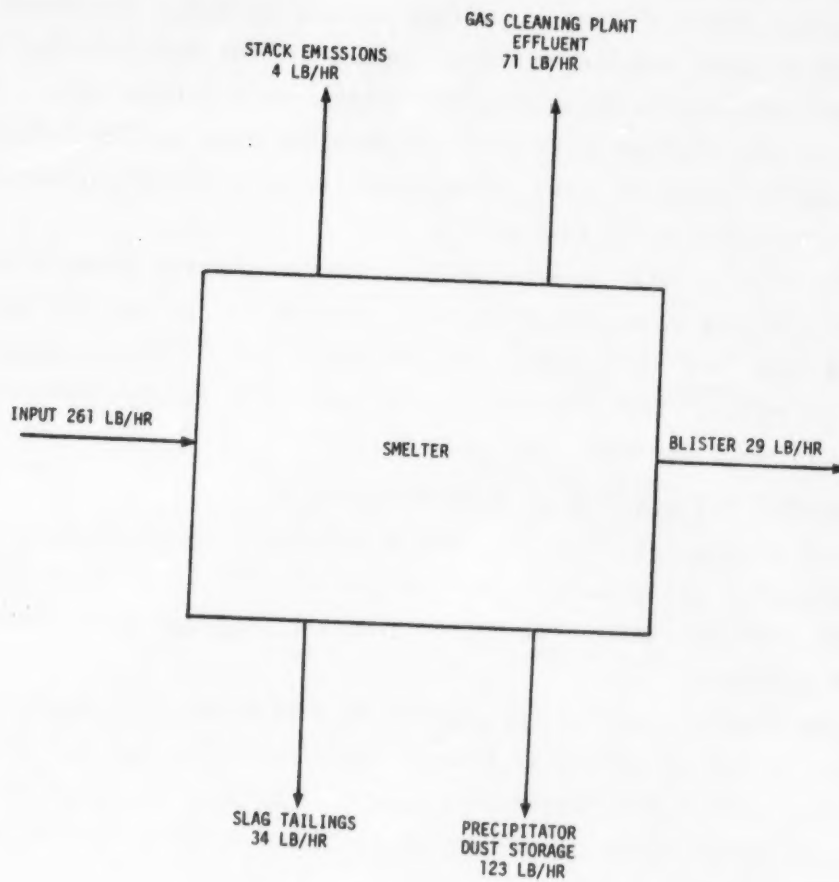


Figure F-5(b). Overall Arsenic Material Balance at Kennecott-Garfield Smelter

F.6 ARSENIC DISTRIBUTION AT KENNECOTT-HAYDEN

Kennecott Copper Company provided EPA with arsenic distribution data for the Hayden smelter in March 1983.² These data, however, did not give a closed material balance, with 13 percent of the total input arsenic unaccounted for. Additionally, insufficient data were provided to calculate arsenic rates in various process streams. Therefore, only the smelter input arsenic rate from the March 1983 data provided by Kennecott was used in developing the arsenic mass balance data. Information on distribution of arsenic was obtained from earlier information^{5,6} submitted by Kennecott. The arsenic mass balance for the Kennecott-Hayden smelter is presented in Figure F-6.

The arsenic rates for the various smelter streams shown in the material balance were proportionately adjusted to reflect the recent data on feed rate indicated by the company. The difference between the adjusted arsenic rates and the arsenic rates provided by Kennecott were not significant for some streams.

F.7 ARSENIC DISTRIBUTION AT KENNECOTT-HURLEY

The arsenic mass data provided by Kennecott Copper Company for the Hurley smelter are presented in Figure F-7.² The data represent the arsenic distribution for the flash furnace technology to be installed at the smelter.

The arsenic input to the smelter is 2.14 lb/hr. The data indicate that 49 percent of the total arsenic input including the recycle material is volatilized in the flash furnace, and 14 percent is volatilized in the converters. Also, 31 percent of the total arsenic is slagged in the flash furnace.

F.8. ARSENIC DISTRIBUTION AT KENNECOTT-McGILL

An arsenic mass balance for the Kennecott-McGill smelter is presented in Figure F-8. Data for the mass balance were provided to EPA by the Kennecott Copper Company;² however, a few assumptions were necessary to obtain a closed balance. An arsenic collection efficiency of 30 percent was used for the reverberatory furnace electrostatic precipitator. The final arsenic distribution indicates that 21 percent of the input arsenic to the smelter is

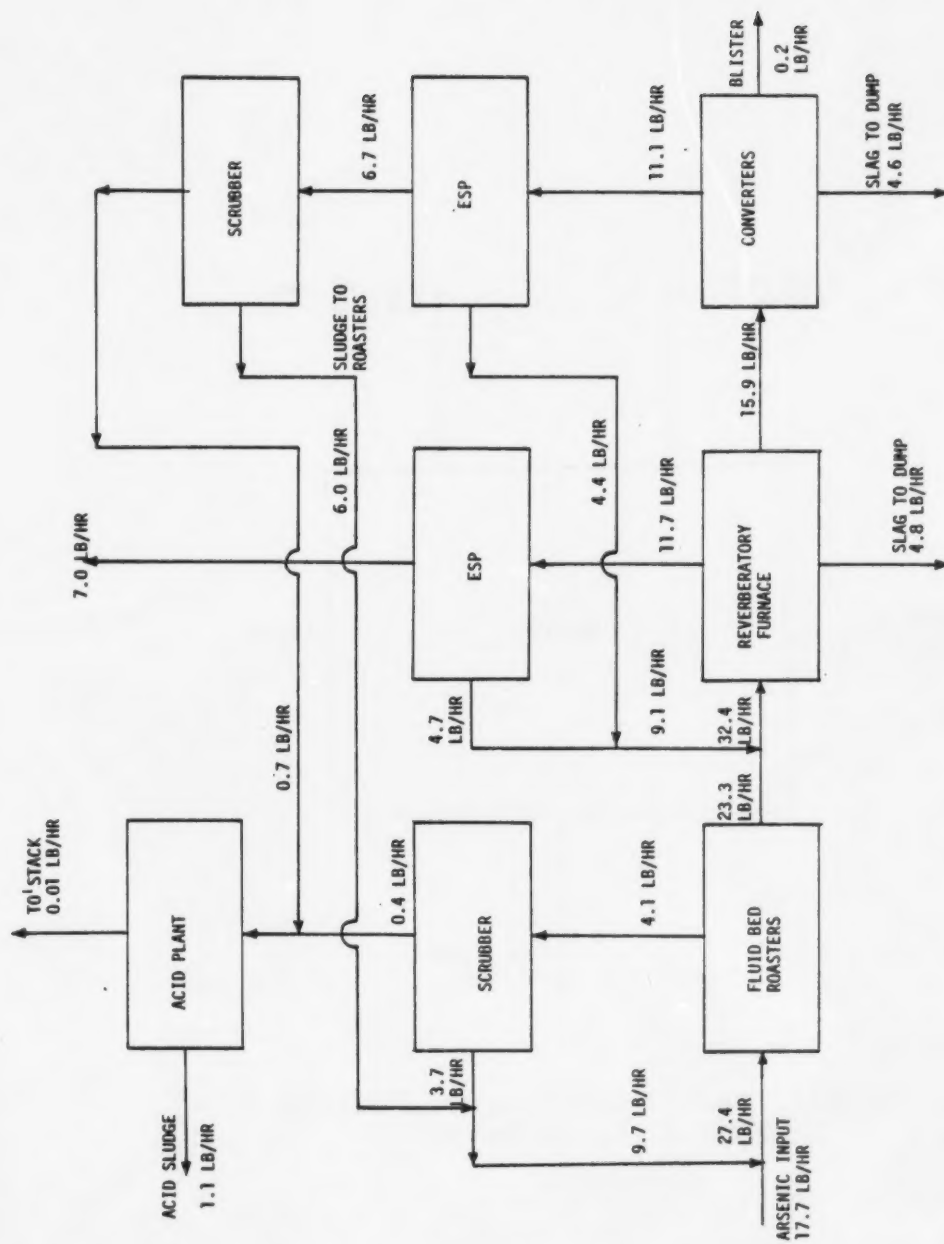


Figure F-6(a). Arsenic Distribution at Kennecott-Hayden Smelter

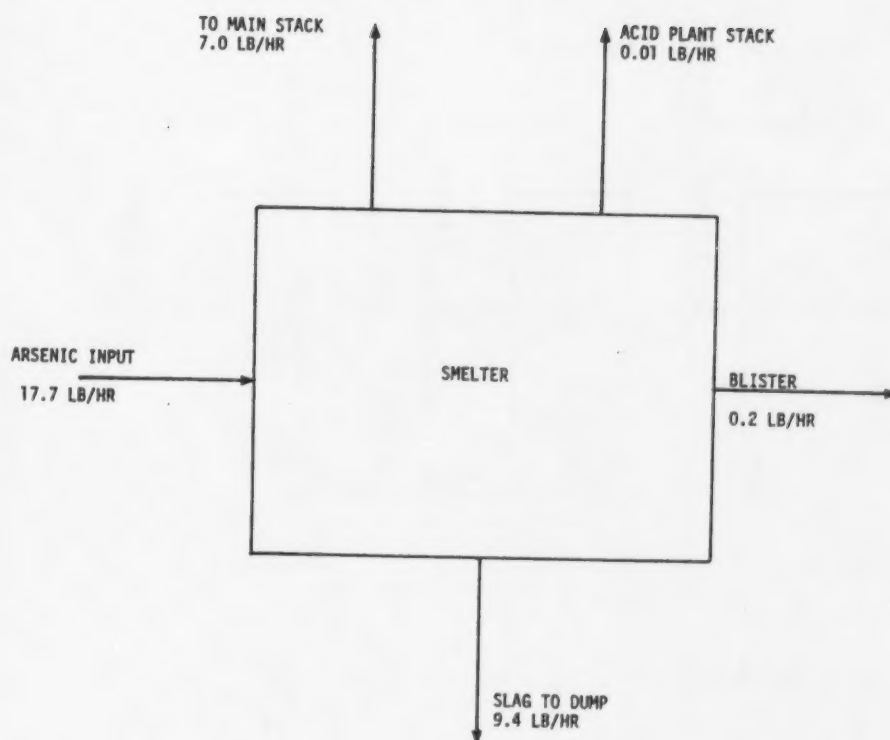


Figure F-6(b). Overall Arsenic Material Balance at Kennecott-Hayden Smelter

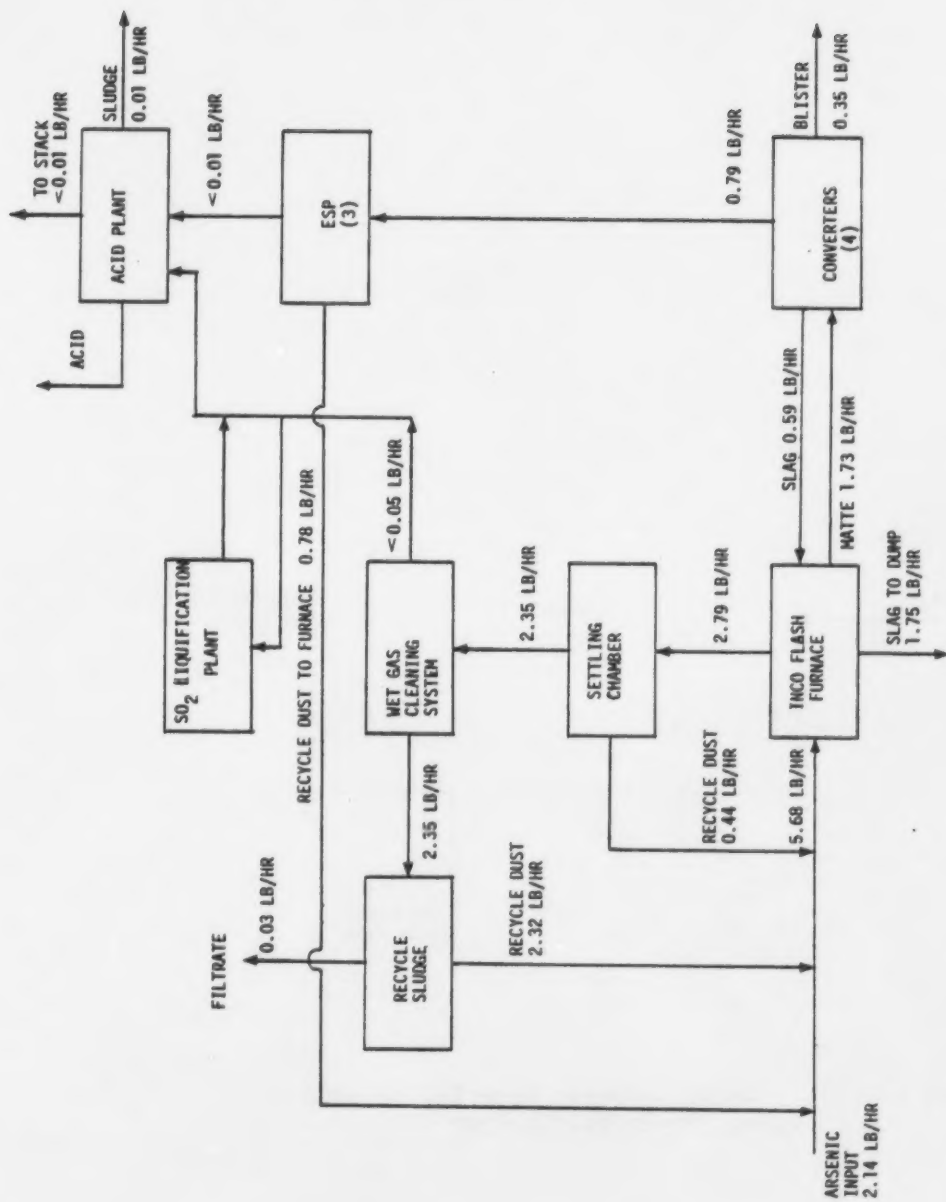


Figure F-7(a). Arsenic Distribution at Kennecott-Hurley Smelter

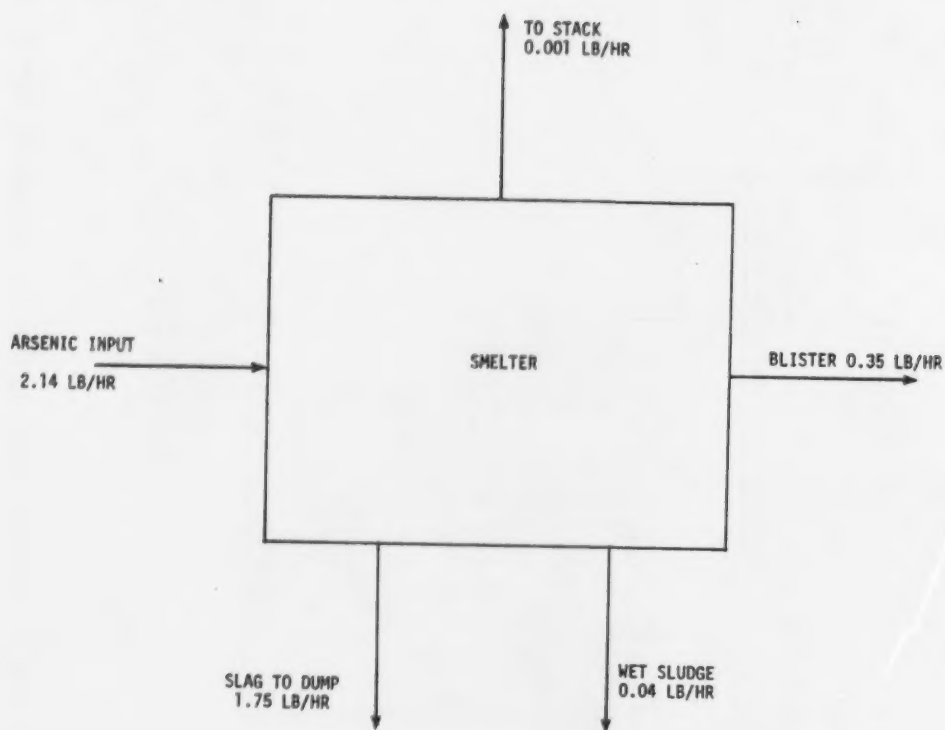


Figure F-7(b). Overall Arsenic Material Balance at Kennecott-Hurley Smelter

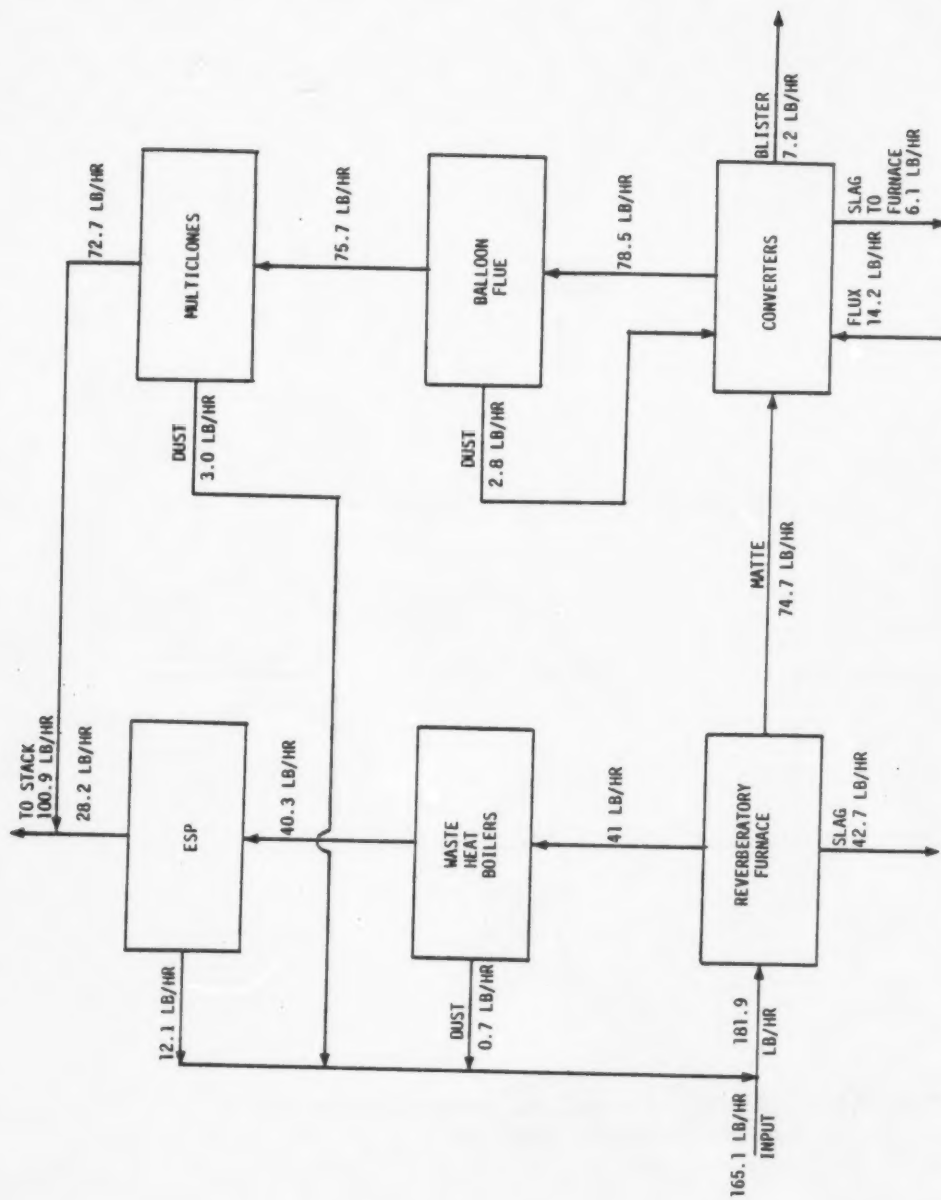


Figure F-8(a). Arsenic Distribution at Kennecott-McGill Smelter

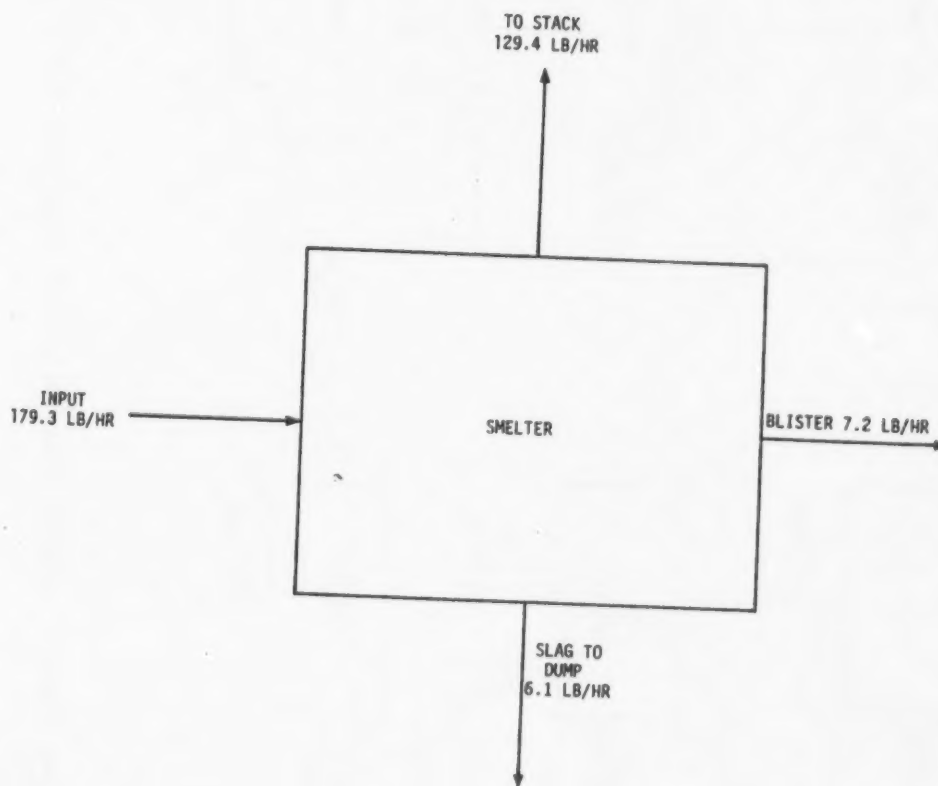


Figure F-8(b). Overall Arsenic Material Balance at Kennecott-McGill Smelter

volatilized in the reverberatory furnace, 22 percent reports in the slag, and 40 percent is volatilized in the converter.

F.9 ARSENIC DISTRIBUTION AT MAGMA COPPER COMPANY-SAN MANUEL

Magma Copper Company provided to EPA material balance data based on the arsenic content of the concentrate blend expected to be used in the future.^{7,8} This information, obtained through EPA information request letters, was used to develop the arsenic mass balance for the Magma smelter given in Figure F-9.

F.10 ARSENIC DISTRIBUTION AT PHELPS DODGE-AJO

An arsenic mass balance for the Phelps Dodge-Ajo smelter is presented in Figure F-10. This balance is developed based on the arsenic input rate to the smelter provided by Phelps Dodge Corporation,⁹ and on arsenic distributions determined for various streams from EPA's letter of information request to Phelps Dodge.¹⁰ This material balance assumed a 25 percent collection efficiency for the reverberatory furnace ESP and that the furnace offgases from the ESP are treated in the converter acid plant. Phelps Dodge Corporation provided EPA with test data indicating 69 percent efficiency for the reverberatory furnace ESP. Development of a closed arsenic material balance was not possible using the arsenic distribution data indicated in Figure F-10 and the ESP precipitator efficiency data provided by the company. Therefore, the efficiency provided by Phelps Dodge was not used in the material balance.

F.11 ARSENIC DISTRIBUTION AT PHELPS DODGE-DOUGLAS

Information currently available from the smelter¹¹ indicates that approximately 24 lb/hr of arsenic is input with the concentrate to the roasters. The weight percent of arsenic in the concentrate is approximately 0.03, and the total feed to the roaster is about 1,200 tpd. The arsenic profile for Phelps Dodge-Douglas was obtained from the smelter; however, the information given was limited, and a complete arsenic balance was therefore not possible.

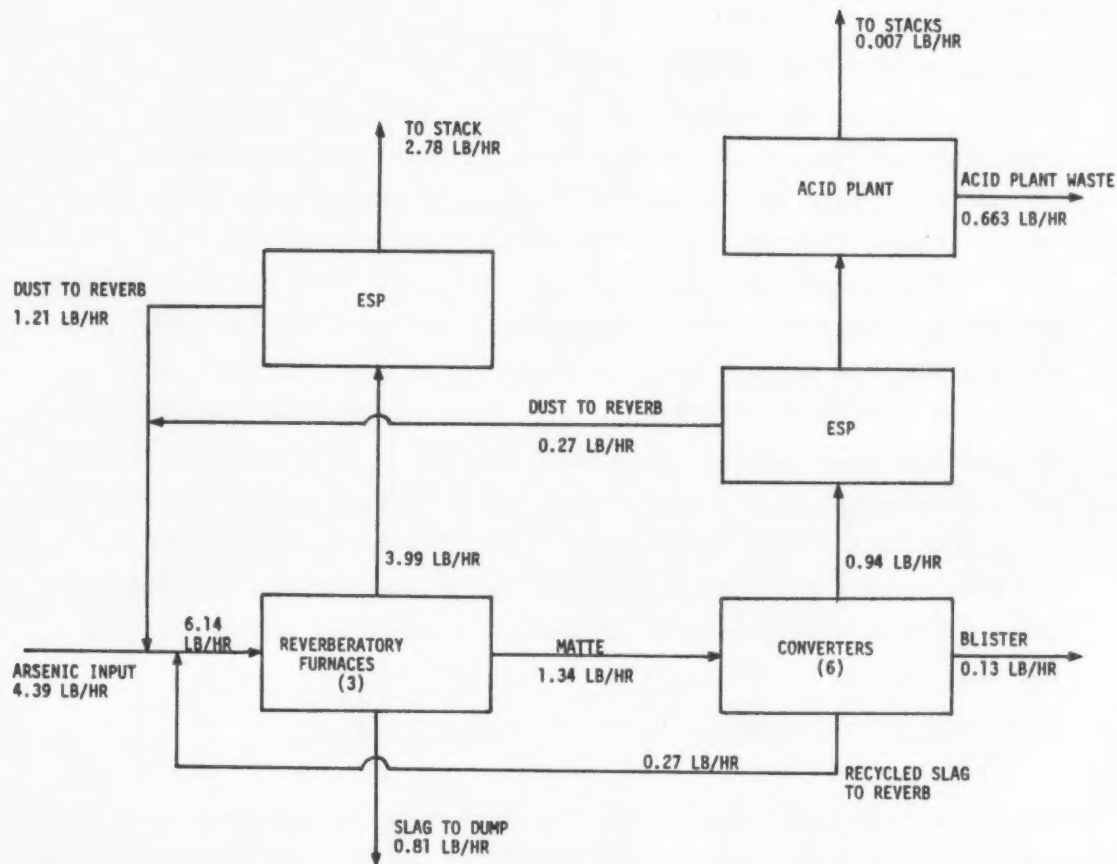


Figure F-9(a). Arsenic Distribution at Magma Copper Company-San Manuel Smelter

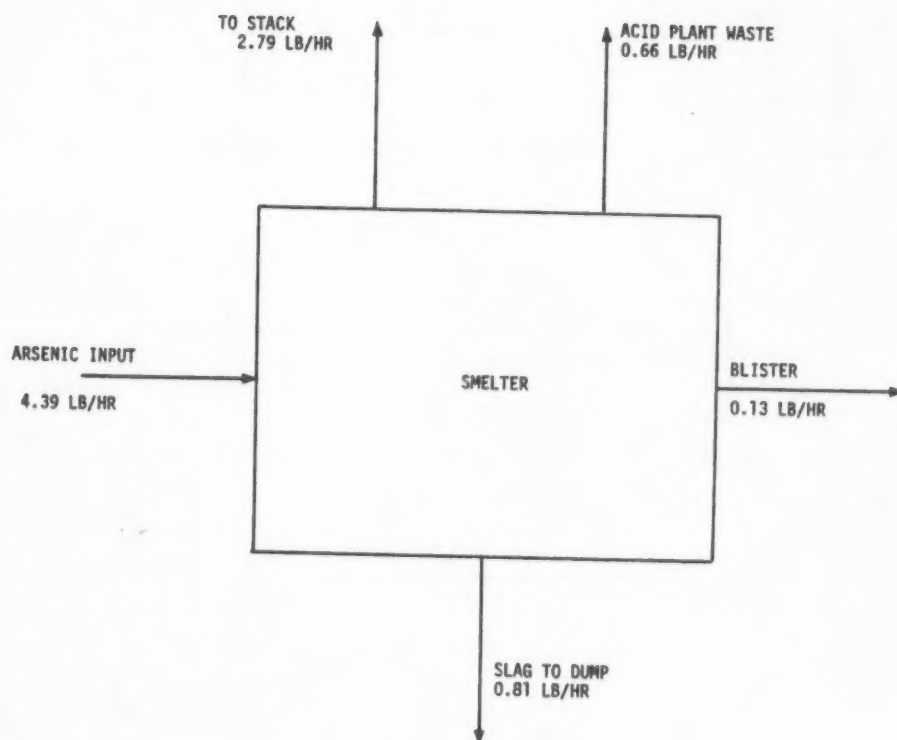


Figure F-9(b). Overall Arsenic Material Balance at
Magma Copper Company-San Manuel Smelter

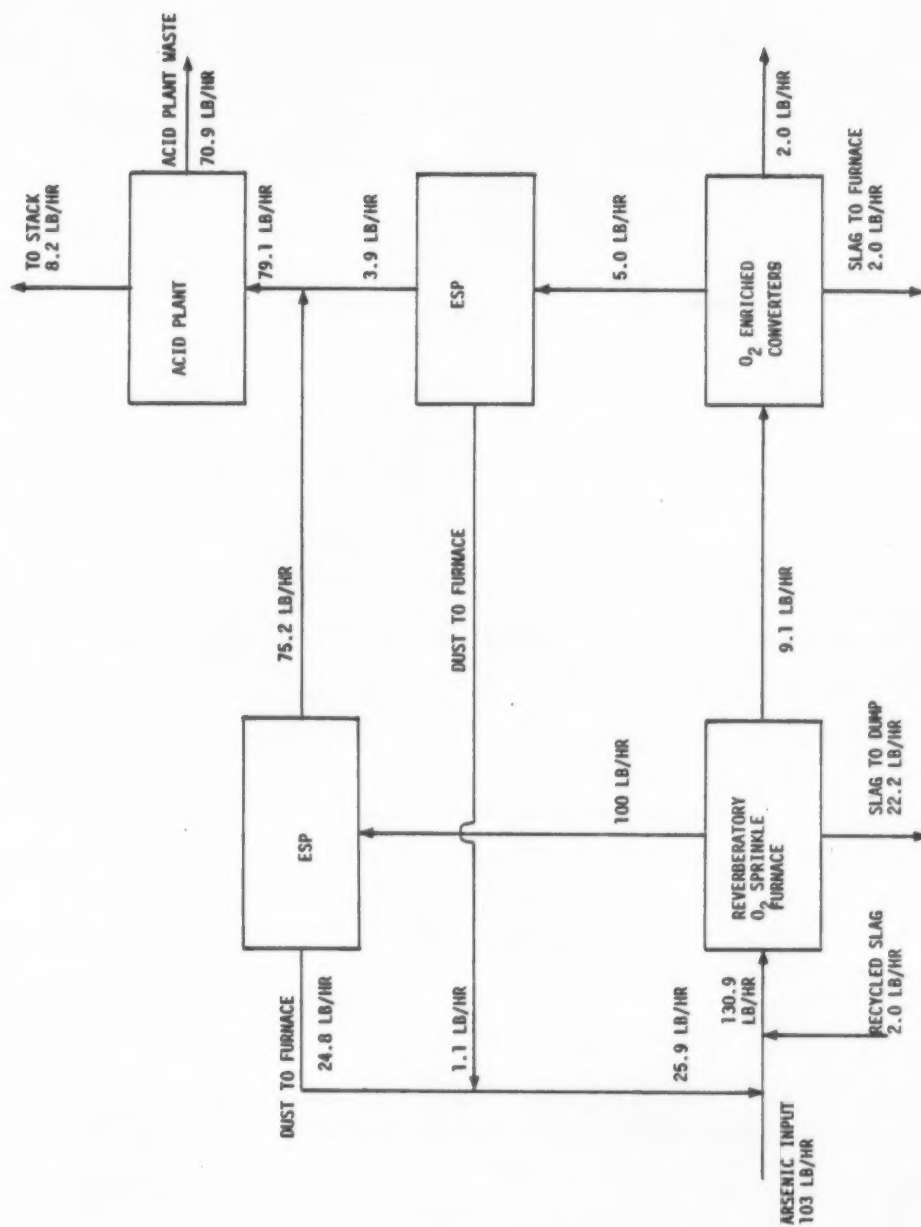


Figure F-10(a). Arsenic Distribution at Phelps Dodge-Ajo Smelter

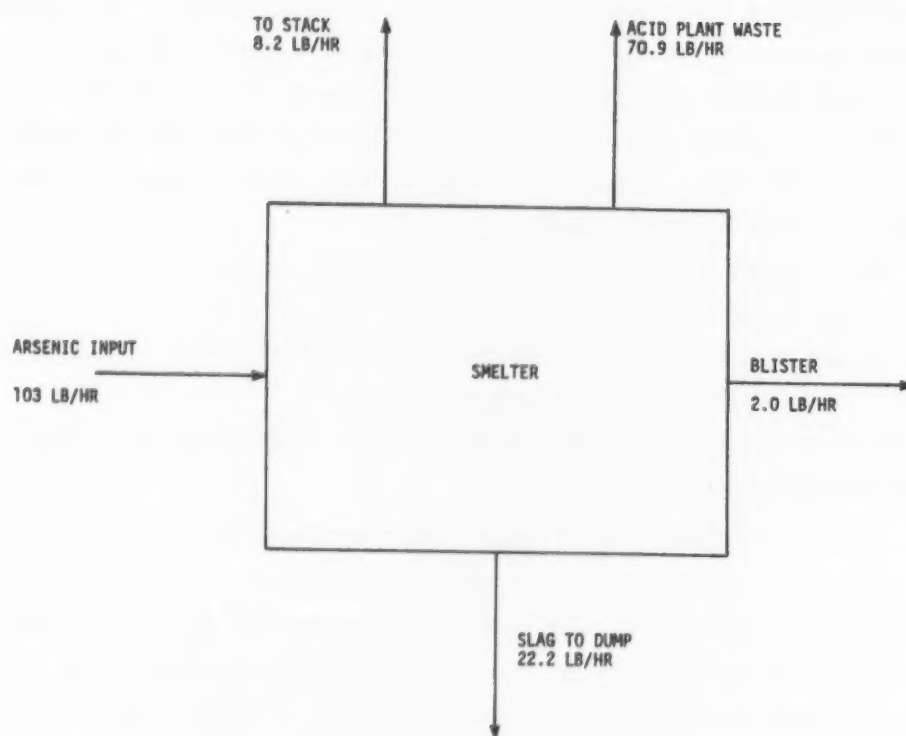


Figure F-10(b). Overall Arsenic Material Balance at Phelps Dodge-Ajo Smelter

The arsenic distribution obtained at the Bor, Yugoslavia, smelter is for a similar smelting configuration;¹² however, there is variation in the percent arsenic volatilized or slagged in the furnace and converter depending upon the amount of arsenic volatilized in the multi-hearth roaster.

To obtain the arsenic mass balance shown in Figure F-11, it was assumed that 17.5 percent of the arsenic is volatilized in the roaster, since this is the average of the range obtained at the Bor.¹² However, 45 percent of the arsenic was assumed to be slagged in the reverberatory furnace and 7 percent was assumed to be volatilized. This distribution was used because of the high amount of arsenic reported by the smelter to be found in the reverberatory slag. In the converter it was assumed that 23.2 percent of the input arsenic is volatilized and 5.8 percent reports in the slag. Only 1.5 percent of the input arsenic was assumed to remain in the blister copper.

The collection efficiency of the hot electrostatic precipitators was assumed to be 30 percent.

The arsenic mass balance obtained showed that about 9.4 lb/hr of arsenic is emitted to the atmosphere. About 13.7 lb/hr of arsenic is removed with the reverberatory slag, and 0.5 lb/hr of arsenic reports in the blister copper.

F.12 ARSENIC DISTRIBUTION AT PHELPS DODGE-HIDALGO

An arsenic mass balance for the Phelps Dodge-Hidalgo smelter is presented in Figure F-12. In April 1983, Phelps Dodge provided overall mass balance data for the smelter.⁹ However, the data were insufficient to develop the material balance for each piece of process equipment. Therefore, the arsenic balance shown in Figure F-12 was developed by using the arsenic input rate to the smelter provided in April 1983 by Phelps Dodge and the arsenic distribution in various streams from EPA's information request sent to Phelps Dodge.¹⁰

F.13 ARSENIC DISTRIBUTION AT PHELPS DODGE-MORENCI

An arsenic mass balance for the Phelps Dodge-Morenci smelter is presented in Figure F-13. The information was provided to EPA by Phelps Dodge Corporation.⁹

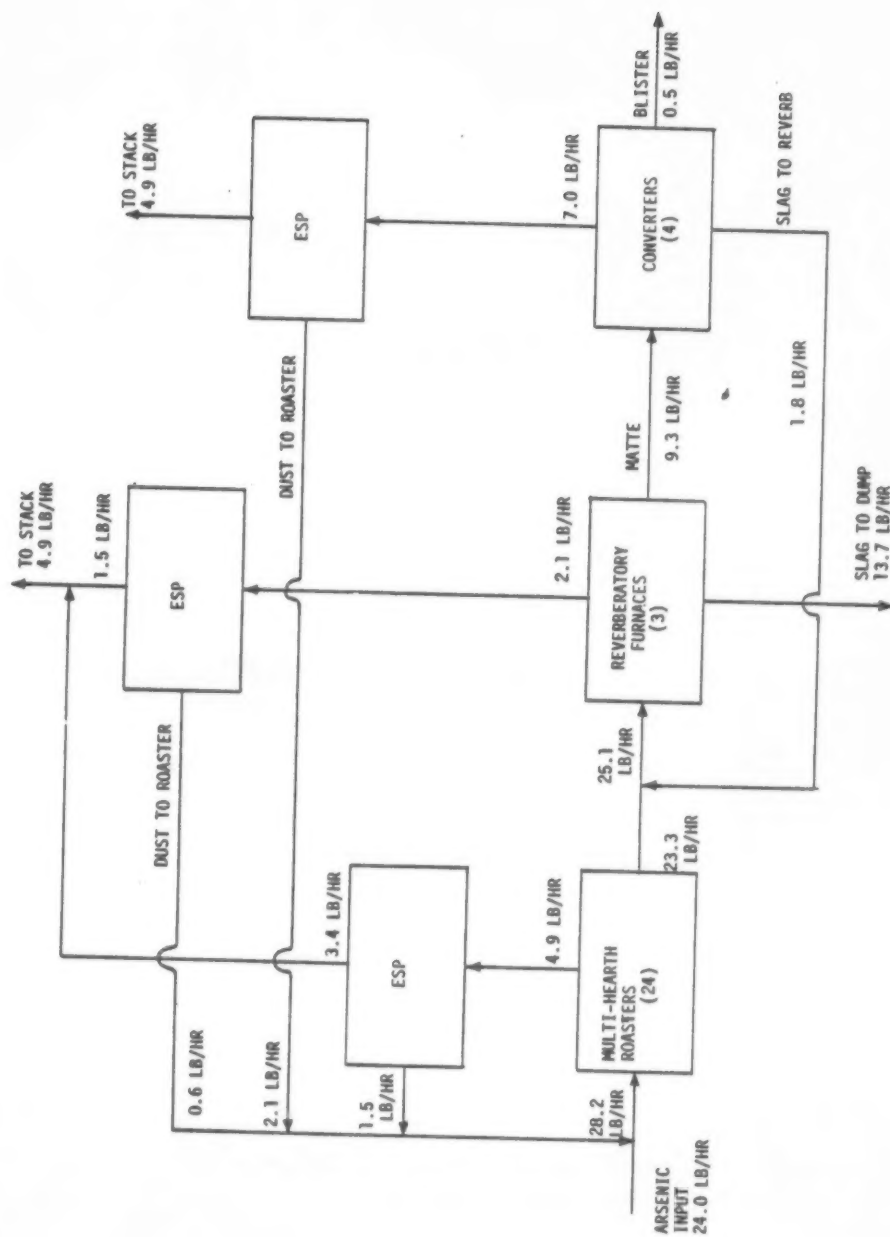


Figure F-11(a). Arsenic Distribution at Phelps Dodge-Douglas Smelter

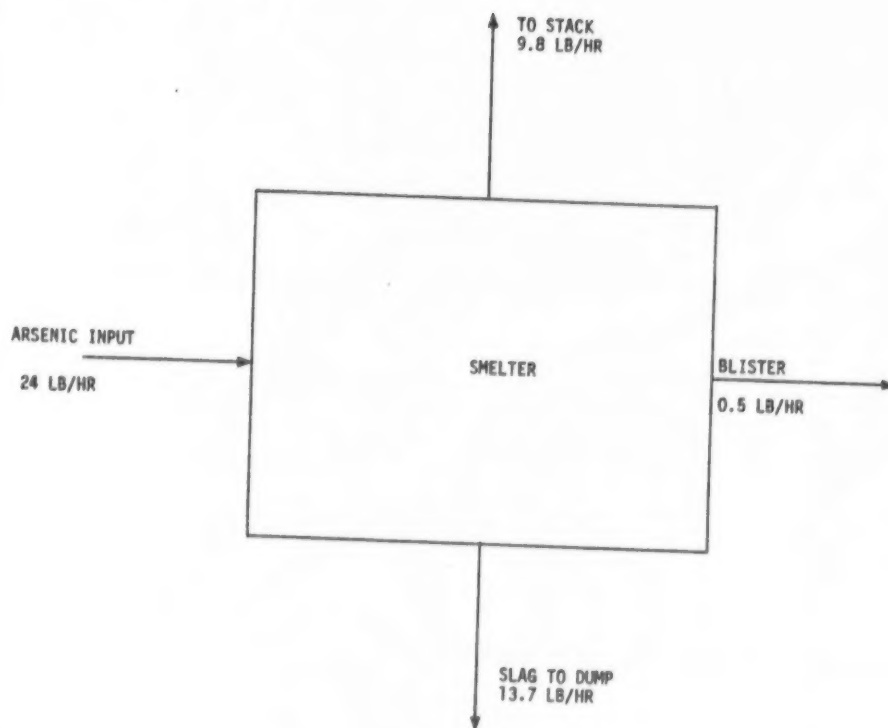


Figure F-11(b). Overall Arsenic Material Balance at Phelps Dodge-Douglas Smelter

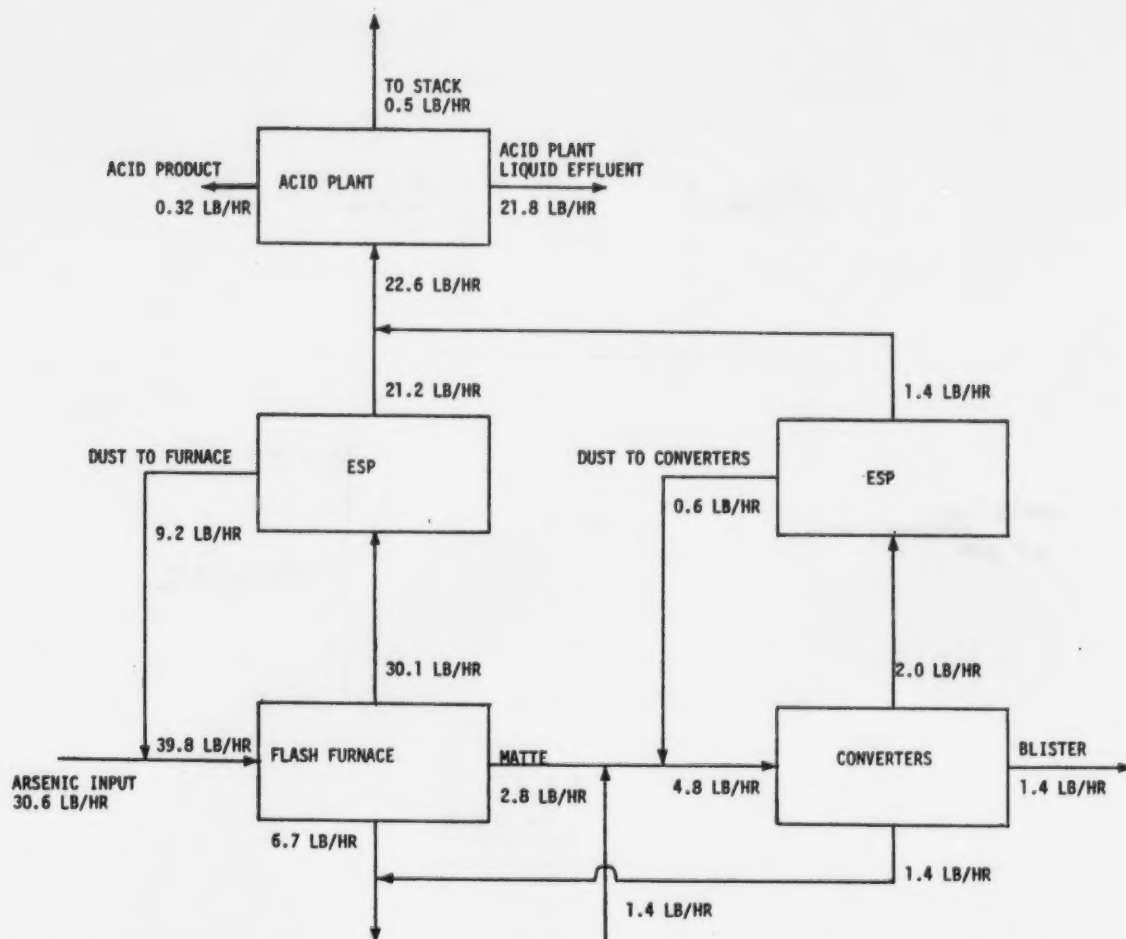


Figure F-12(a). Arsenic Distribution at Phelps Dodge-Hidalgo Smelter

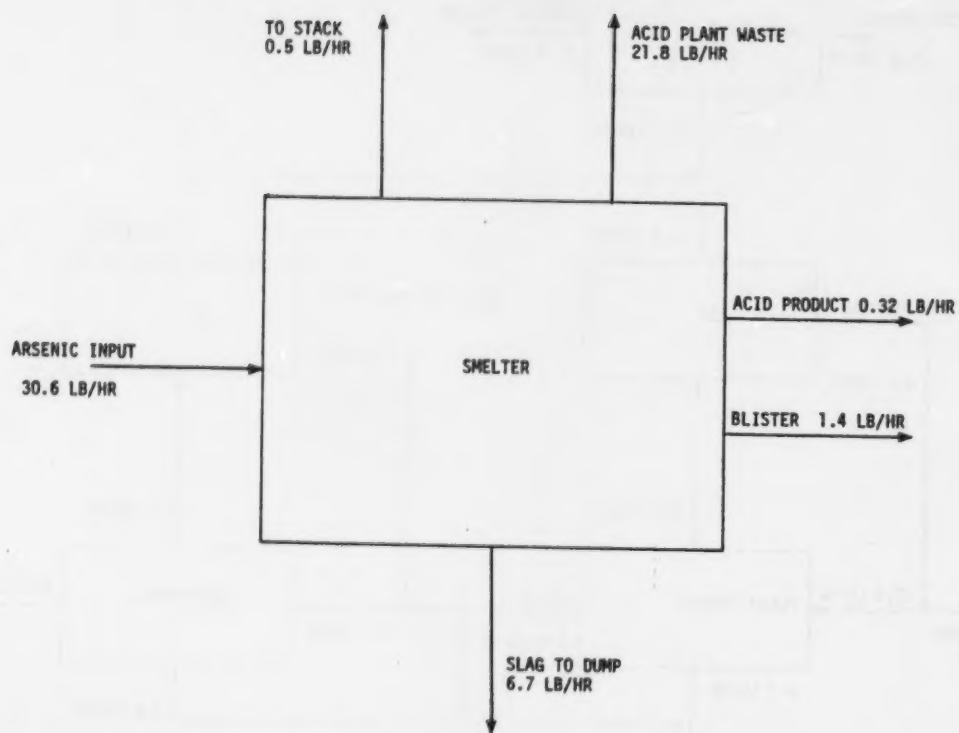


Figure F-12(b). Overall Arsenic Material Balance at Phelps Dodge-Hidalgo Smelter

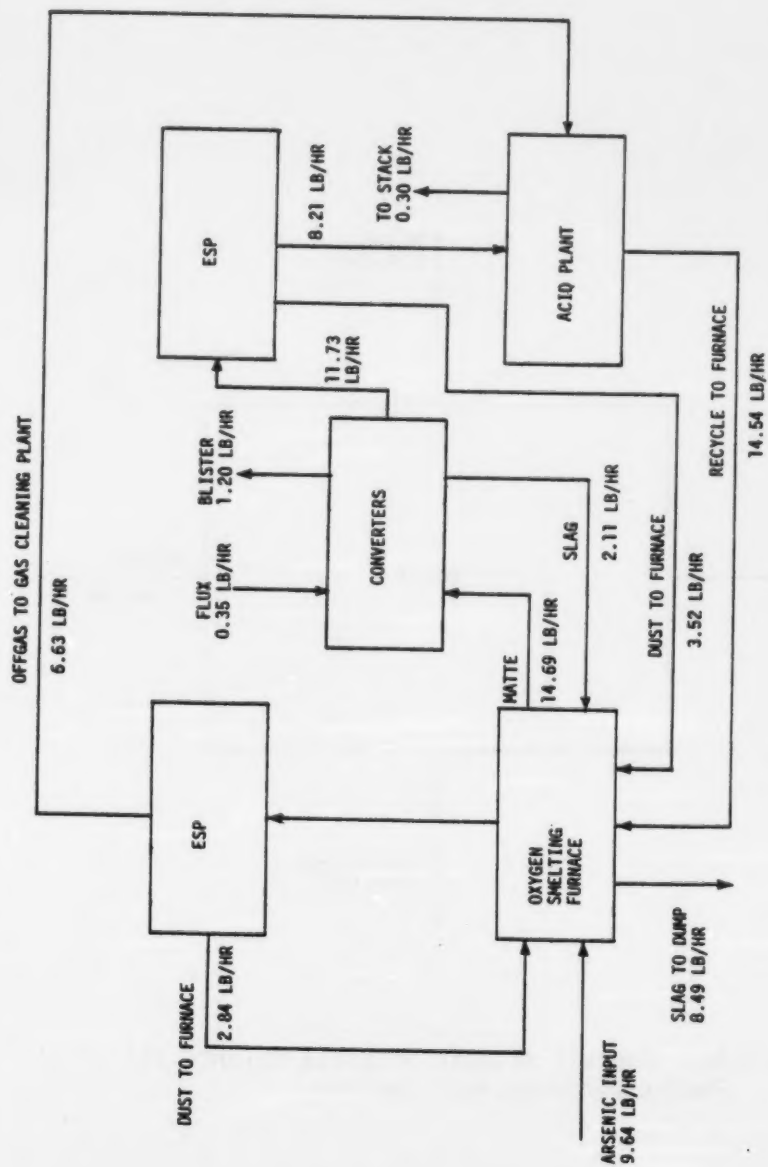


Figure F-13(a). Arsenic Distribution at Phelps Dodge-Morenci Smelter

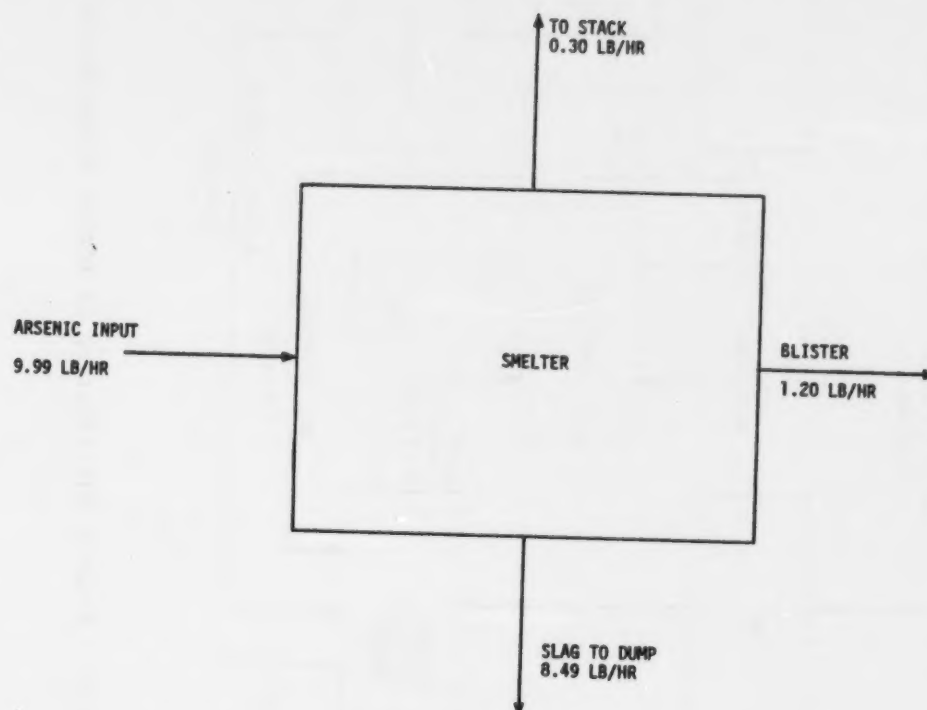


Figure F-13(b). Overall Arsenic Material Balance at Phelps Dodge-Morenci Smelter

F.14 ARSENIC DISTRIBUTION AT COPPER RANGE

The Copper Range Copper Company furnished EPA with information for the White Pine smelter;¹³ however, from those data 46 percent of the arsenic input was unaccountable. The Copper Range Copper Company subsequently advised EPA¹⁴ of corrections necessary to obtain a closed arsenic material balance. The arsenic mass balance presented in Figure F-14 reflects these corrections.

Data suggested by Copper Range Company as a starting point for the material balance were:

Total arsenic input to the furnace	1.52 lb/hr
Arsenic in flux, refining slag and soda slag to converters	0.22 lb/hr
Total Input	1.74 lb/hr
Arsenic in slag to dump	0.50 lb/hr
Arsenic in blister copper	0.43 lb/hr

The above data indicate that 0.81 lb/hr arsenic (i.e., the difference between the input of 1.74 lb/hr and the output of 0.93 lb/hr) occurs as emissions from the furnace and converters. The material balance provided by Copper Range indicated an arsenic emission rate of 0.3 lb/hr from the reverberatory furnace, a figure which EPA deemed reasonable. Therefore, the remaining 0.51 lb/hr arsenic (i.e., the difference between the total estimated arsenic emission rate of 0.81 lb/hr and the 0.3 lb/hr emission rate for the furnace) was assumed emitted from the converters.

The Company-provided data indicate that 0.62 lb/hr of arsenic is recycled to the furnace. Thus, the recycled arsenic (i.e., the amount captured in the waste heat boiler and the electrostatic precipitator system) and the assumed 0.3 lb/hr arsenic emission rate from the reverberatory furnace is 0.92 lb/hr. This value and other arsenic streams to the reverberatory furnace indicate that the arsenic content of the matte must also be 0.92 lb/hr.

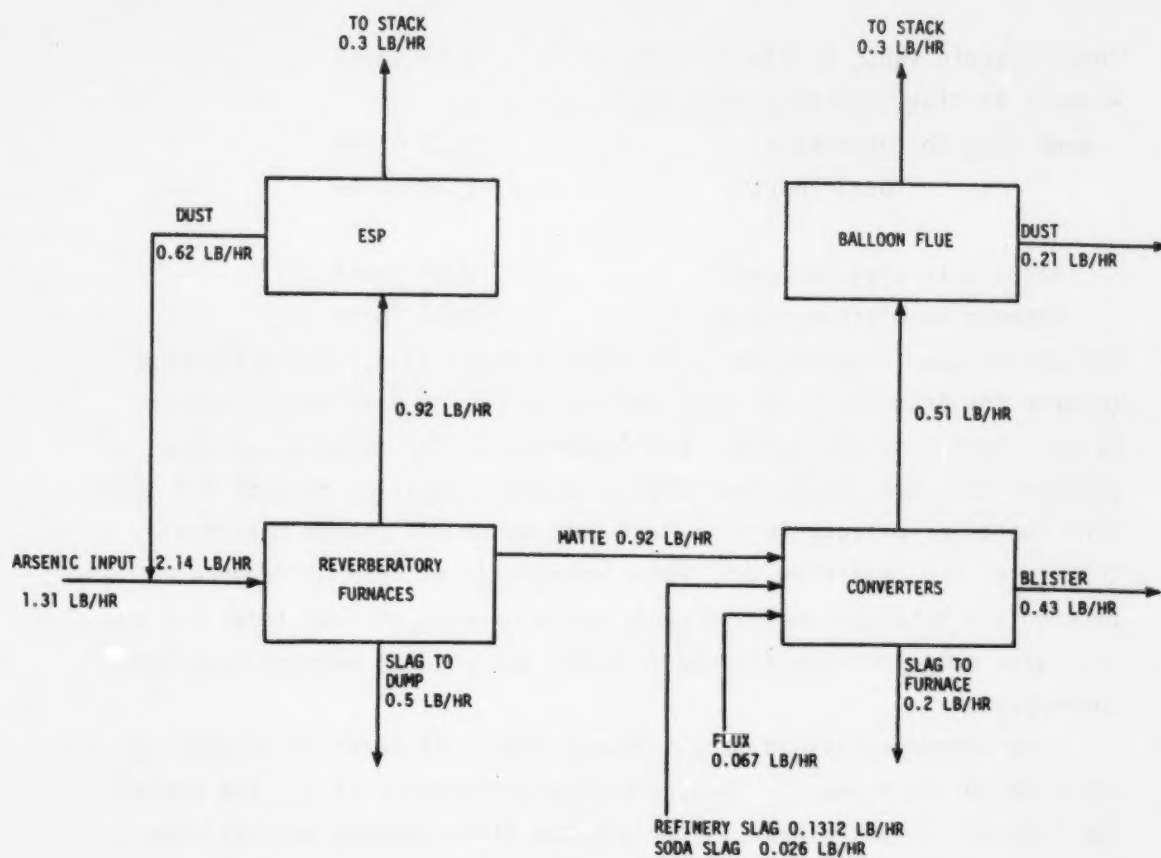


Figure F-14(a). Arsenic Distribution at Copper Range Company Smelter

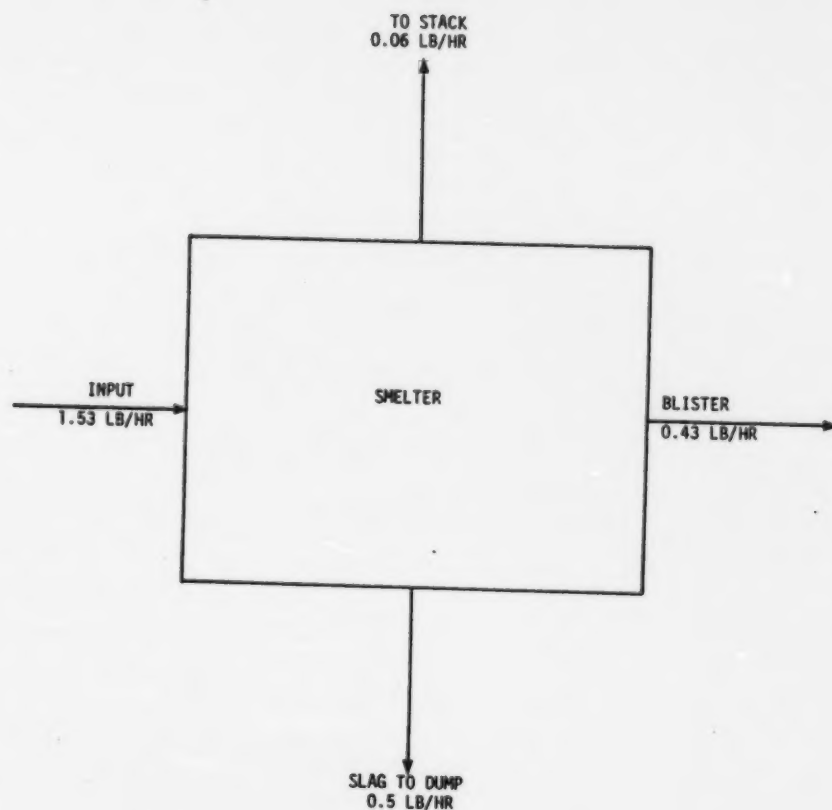


Figure F-14(b). Overall Arsenic Material Balance at Copper Range Company Smelter

The overall arsenic distribution shown in Figure F-14 shows 39 percent of input arsenic (including that recycled to the furnace and that to the converters) is volatilized in the converters. Also, 21 percent of the input arsenic is slagged in the reverberatory furnace and 8 percent is slagged in the converters. The arsenic collection efficiency for the waste heat boiler and electrostatic precipitator is 67 percent. This efficiency value is reasonable based on the actual operating temperature and the control efficiency data EPA collected during source testing at other smelters.

F.15 REFERENCES

1. Letter and attachments from M.O. Varner, ASARCO, Inc., to J.R. Farmer, U.S. Environmental Protection Agency. March 16, 1983. Response to Section 114 information request.
2. Letter and attachments from R.A. Malone, Kennecott Minerals Company, to J.R. Farmer, U.S. Environmental Protection Agency. March 16, 1983. Response to Section 114 information request.
5. Letter and attachments from I.G. Pickering, Kennecott Copper Corporation, to D.R. Goodwin, U.S. Environmental Protection Agency. May 9, 1978. Response to information request about arsenic distribution at Kennecott Copper Smelters.
6. Letter and attachments from R.A. Malone, Kennecott Minerals Company, to D.R. Goodwin, U.S. Environmental Protection Agency. December 23, 1983. Response to Section 114 information request.
7. Letter and attachments from J.H. Boyd, Magma Copper Company, to J.R. Farmer, U.S. Environmental Protection Agency. March 15, 1983. Response to Section 114 information request.
8. Letter and attachments from D.C. Ridinger, Magma Copper Company, to D.R. Goodwin, U.S. Environmental Protection Agency. April 4, 1983. Response to Section 114 information request.
9. Letter from L.R. Judd, Phelps Dodge Corporation to J.R. Farmer, U.S. Environmental Protection Agency. April 7, 1983. Response to Section 114 information request.
10. Letter and attachments from J.R. Farmer, U.S. Environmental Protection Agency, to Phelps Dodge Corporation. 1983. Section 114 information request.
11. Letter and attachments from R.W. Pendleton, Phelps Dodge Corporation, to D.R. Goodwin, U.S. Environmental Protection Agency. June 2, 1983.
12. Stankovic, D. "Air Pollution Caused by Metallurgy Assemblies in Bor." Institute for Copper, Bor, Project No. 02-513-1. U.S. Environmental Protection Agency.
13. Letter and attachments from J.W. Maksym, Copper Range Company, to J.R. Farmer, U.S. Environmental Protection Agency. March 17, 1983. Response to Section 114 information request.

14. Telecon. Katari, V., Pacific Environmental Services, Inc., with J.W. Maksym, Copper Range Company. Arsenic material balance for White Pine Copper Smelter. March 31, 1983.

TECHNICAL REPORT DATA <i>(Please read Instructions on the reverse before completing)</i>		
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	6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.	
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17. KEY WORDS AND DOCUMENT ANALYSIS		
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